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CORRECTIONS

MONTHLY WEATHER REVIEW SUPPLEMENT No. 26 (An Aerological Survey of the United States, Part II)

The values in the following table should be substituted for those under Group 9, summer and annual, in Table 3, page 7:

Altitude (meters)	Summer		Annual	
	Direction	Velocity	Direction	Velocity
Surface	S. 24 E.	3.9	S. 42 E.	4.6
250	S. 15 E.	5.1	S. 19 E.	6.3
500	S. 14 E.	5.6	S. 16 E.	7.0
750	S. 12 E.	5.5	S. 12 E.	7.3
1,000	S. 9 E.	5.3	S. 4 E.	7.4
1,500	S. 4 E.	5.2	S. 21 W.	7.8
2,000	S. 6 E.	5.2	S. 65 W.	8.4
3,000	S. 11 E.	5.5	S. 77 W.	10.0
4,000	S. 2 W.	6.2	S. 83 W.	11.7
5,000	S. 56 E.	6.9	N. 88 W.	13.6
6,000	N. 3 E.	7.8	N. 51 W.	15.1
8,000	N. 33 E.	9.8	N. 29 W.	19.1
10,000	N. 48 E.	11.2	N. 32 W.	23.0

MONTHLY WEATHER REVIEW, November, 1926:

Page 455 (paper on "Graphical Thermodynamics of the Free Air"), *instead of* "and (4)" just preceding equation (12), *read:* "and the nonadiabatic form of Poisson's equation, viz, $T/T_0 = (\theta/\theta_0)\ (p/p_0)^{AR/c_p}$."—*E. W. W.*

MONTHLY WEATHER REVIEW, February, 1927:

Page 62, the legend to figure 3 should read: "Rainfall periodogram of the Punjab (entire data series)"; the legend to figure 4 should read: "Rainfall periodogram of the British Isles."

MONTHLY WEATHER REVIEW

Editor, ALFRED J. HENRY — Assistant Editor, BURTON M. VARNEY

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INTERPRETATION OF CORRELATION COEFFICIENTS

By C. F. MARVIN

A paper of great scientific and practical importance has been published under the above title by S. Krichewsky, Technical Assistant, Ministry of Public Works, Egypt, Physical Department Paper No. 22, 1927.

Prior to 1921, students employing correlation coefficients in the investigation of scientific questions were accustomed to gauge the significance of a coefficient by its magnitude and probable error. Mr. W. H. Dines[1] showed that—

> If there is a cause A and a result M with a correlation r between them, then in the long run A is responsible for r^2 of the variation of M.

Krichewsky points out that, although the validity of the r^2 or Dines' law was known to be based on the assumption that the cause A must be entirely independent of other contributory causes, B, C, etc., to variations of M, and therefore limited in its application, nevertheless this limitation has been so lightly emphasized that research workers may easily disregard its fundamental assumptions. In fact, he quotes a sentence in the article by the present writer on the question of day-to-day fluctuations of the solar constant[2] as an actual example of the misapplication of the r^2 law.

In discussing a table giving, among others, the correlation coefficient +0.69 between E_0, the bolographic solar constant and A_0 the pyrheliometer readings extrapolated by straight lines to zero air mass, I stated that "the coefficient +0.69, interpreted by Dines' law, means that 48 per cent of day-to-day variation in these two values of the solar constant, which are derived from the same parent data, occur in synchronism." This application of the r^2 law is of course a technical error, because E_0 and A_0, drawn from the same parent data, are obviously affected by covariation, due to possible changes in solar intensity, plus interrelated causes. The effect of this error on my analysis was to cause me to assign only 48 per cent as the measure of synchronism of E_0 and A_0, due to a common cause, whereas Krichewsky now claims that "more than 69 per cent of the variation of E_0 occurs in synchronism with less than 69 per cent of the variation of A_0 as a result of the common factor $I_0 + a$, provided the individual errors of these two values of the solar constant are mutually uncorrelated."

Asking the question, is Krichewsky not himself in error in the application of his extended r^2 law to the particular case under consideration, I wish to make it plain that while writing my paper I was fully aware that a high relationship must exist between E_0 and A_0 as shown by the following words which immediately precede those quoted by Krichewsky:

> Errorless values of E_0 and A_0 should show a high correlation, unless the fortuitous differences betweeen them due to polychromatic radiation, as distinguished from all other causes of error, are themselves inherently large. This is a matter deserving fuller investigation.

This statement is, I believe, absolutely correct, provided I_0, the solar intensity is truly variable, otherwise the whole question takes on another aspect, which we mean to discuss presently.

In spite of the technical misapplication of Dines's law, the general correctness of my interpretation of the significance of the correlation coefficients has not been vitiated by Krichewsky's criticism in any material way. Believing this claim is fully justified, I now wish to analyze more closely Krichewsky's equation (3), page 3, as it applies to solar observations. The object is to indicate why it does not seem to be applicable to the correlation +0.69 between E_0 and A_0 and to examine its utility in a more general way.

Writing Krichewsky's law in the form of an equation, it is:

$$r_{12} = r_1 \, r_2 \tag{3}$$

in which, as applied to solar observations, we may say r_1 and r_2 are the respective coefficients of correlation between the true solar intensity I_0 outside the earth's atmosphere and two measured effects M_1 and M_2 between which there is the correlation r_{12}. M_1 and M_2 also vary under two respective separate causes B and C, both independent of I_0 and of each other, and which may indeed be only errors of observation. The final assumption is that the variables are in linear relationship. The values E_0 and A_0 drawn from the same parent data can not be put in the place of M_1 and M_2 because B and C as other causes of variation, while independent of I_0, are both functions of atmospheric transparency, and in addition comprise errors of observations of the pyrheliometer which are common in their effects upon both E_0 and A_0. Krichewsky was probably not aware of the intimacy of relationship between the errors of E_0 and A_0. In any case it was the above reasoning which caused me to ask the question I did.

The foregoing, moreover, leads to one or more important corollaries:

(1) Solar constant values like E_0, A_0, or any other value drawn from a given body of parent observations on the same days and at a single station can not satisfy the fundamental assumptions underlying equation (3).

(2) Homogeneous values of E_0 at two widely separated stations may represent M_1 and M_2 in Krichewsky's problem; provided, first, that the values are nearly simultaneous, but especially that they are not previously artificially correlated by corrections and adjustments based upon interstation comparisons or other treatment that impairs the complete independence of the station values, and provided, second, that the losses by atmospheric

[1] Meteorological Magazine, February, 1921, p. 20.
[2] MONTHLY WEATHER REVIEW, July, 1925, 53: 295.

absorption do not cause more or less the same systematic effects at both stations, such as shown by annual periodicity in values of E_0 or the negative correlation of E_0 and air transparency a.

(3) Homogeneous values of E_0 at a single station, but separated by a sufficiently long interval of time, as a fortnight, a month, or otherwise, might be used as values of M_1 and M_2, provided the covariation due to atmospheric transparency at the separate intervals were entirely independent, thus satisfying the fundamental assumptions.

It is very doubtful if any existing values of E_0 at separate stations are sufficiently free from artificial as well as physical correlations due to terrestrial cause to justify the labor of analyzing them by means of the relationships Krichewsky has developed.

The full significance of the simple relations presented by equation (3) is so well stated by its author that we can not do better than quote him in full:

(a) The two unknown coefficients r_1 and r_2 can not be determined from r_{12} unless some additional information exists about their mutual relation.

(b) Neither of the two is smaller than r_{12}, otherwise one of them would be greater than unity, which is impossible. Hence the values of r_1 and r_2 lie between r_{12} and unity.

(c) The equation (3) may be written

$$r_{12}=\sqrt{r_1^2\ r_2^2} \tag{4}$$

which means that the correlation coefficient between M_1 and M_2 is equal to the geometric mean of the actual variations occurring in both owing to the action of A. [Same as I_o, C. F. M.]

Two important corollaries may be drawn from (4).

(*i*) If the values of r_1 and r_2 be unequal, say $r_1<r_2$ then

$$r_1^2<r_{12}<r_2^2 \tag{4a}$$

(*ii*) If $r_1=r_2=r$ then

$$r_{12}=r^2 \tag{4b}$$

So it appears that in this particular case the coefficient of the correlation itself and not its square is the true measure of the percentage of covariation occurring in the two variables owing to a third controlling factor. It may be of interest to point out that the relation (4b) might be used to calculate $r=\sqrt{r_{12}}$ in order to estimate A from the data given by two instruments M_1 and M_2 or two observers working simultaneously and known to be of equal precision.

In this connection the following formulæ should be added. Squaring and adding up each of the equations (1) we obtain the relations.

$$\sigma_1^2=r_1^2\ \sigma_1^2+\sigma_b^2 \tag{5}$$

$$\sigma_1^2=r_2^2\ \sigma_2^2+\sigma_c^2$$

which allow of estimating the relative magnitudes of r_1 and r_2 or even their exact values in case the standard deviations or the ratios σ_b/σ_1 and σ_c/σ_2 are exactly known. If only one of the latter is known the formula (3) furnishes the second relation to solve for r_1 and r_2.

The equations (5) may be interpreted that in the long run, A is responsible for r_2 of the scatter occurring in M as measured by the square of its standard deviation. This fact is nothing else than Dines's law.

(d) Lastly, let us add the useful interpretation of the formula (3) that the correlation coefficient r_1 between M_1 and its true controlling factor A is reduced by r_2 per cent, and becomes r_{12} in case M_2 is substituted for A to represent it with a degree of precision measured by r_2.

We now come to the most important aspect of the whole question of interpretation.

Equation (3) and all the relations and deductions that precede are based upon the pure assumption that I_0 is really an independent variable. However, the magnitude and nature of possible variations in I_0 have not as yet been conclusively disclosed and evaluated. Accordingly, we are fully justified in making the assumption that I_0 is a constant within limits of the precision of measurements of M_1 and M_2. How must the correlation coefficient r_{12} be interpreted under this assumption? Obviously r_1 and r_2 are simply nonexistent and r_{12} is simply the covariation due to B and C, which in the case of solar measurements at a single station not only comprise independent instrumental errors of different kinds but also errors in common and effects due to atmospheric transparency. I believe no one has computed actual values of r_{12} so we can hardly say what will be found even if data satisfying the basic assumptions were available.

If I_0 is constant then errorless values E_0 would have to be strictly a constant and A_0 a variable depending upon the effects which arise from extrapolation of pyrheliometer readings to zero air mass by straight lines. The coefficient +0.69 must therefore be interpreted to mean that a comparatively large part of the pyrheliometer and bolographic fluctuations which originate in the initial observations and measurements ***are extrapolated to zero air mass.***

If we *assume* solar variability, then equations like (3) will seem to support solar variability. On the other hand, if interpreted on the assumption that I_0 is constant, the same correlation coefficients (like r_{12}) represent nothing whatever but local terrestrial and instrumental effects. This is peculiarly the case in the analysis of solar data because the total fluctuations are quantitatively very small.

In my earlier paper I set up three simultaneous equations (10), (11), (12), pages 289 and 290, in MONTHLY WEATHER REVIEW, July, 1925, by which the solar variability could be computed from independent observations at two stations. Owing to the lack of suitable observations up to the present time it has never been possible to apply these equations in any practical way. I am now impressed, however, with the importance of repeating a word of caution I expressssed in the earlier article and which must always govern the interpretation we put upon results secured from equations based upon certain hypothetical assumptions which may not in fact be justified. The quotation reads:

The mathematician recognizes, of course, that securing a seemingly rational and finite value of σ_1 [solar variations] in the solution of the three equations for a group of simultaneous observations is no proof of solar variability. Having assumed solar variability, a solution of the equations simply apportions to solar variation such part of the total variation as best satisfies the observations at the two stations under the assumed conditions. Some sets of observations may give imaginary roots, and it is obvious that errors of observation can be neither zero nor imaginary.

Solar variation can be shown by these equations only when the results are based on several groups of data from wholly independent stations. As pointed out above, equations of the type of (9) are valid only if σ_1 is unrelated to σ_a or σ_b in magnitude.

In addition to the comparatively simple and elementary portion of Krichewsky's paper discussed in the foregoing, he has extended his analysis to a general investigation of Dines's law. This important addition to the statisticians' facilities for the interpretation of the results of their investigations is discussed in the following paper by Mr. Woolard.

ON THE INTERPRETATION OF CORRELATION COEFFICIENTS IN THE ANALYSIS OF CAUSAL RELATIONS IN PHYSICAL PHENOMENA

By EDGAR W. WOOLARD

It has often been emphasized that statistical investigation includes a great deal more than the mere collection and tabulation of numerical data, and the computation of the various indices and coefficients. The most important, and in general, the most difficult, part of a statistical study is the interpretation of the arithmetical results; in other words, we must distinguish between statistical *description* and statistical *inference*. The determination of the physical meaning of correlation coefficients is a particularly intricate and difficult problem: The importance of a "significiant" coefficient depends jointly on its size and the purposes it is to serve; the coefficient is an index of concomitant variation, but if the regression "equation" formed from it is to be of value for prediction, the variables must be highly correlated (*1*); on the other hand, if correlation has been employed primarily for the purpose of discovering what relations, if any, exist between different variables, a small coefficient is just as likely to give valuable information as a large one. However, the coefficient itself indicates only the resultant covariation due to all the connecting paths of influence, and is no index whatever to physical cause and effect (*2*). We must carefully discriminate between *causal connection* and mere *covariation;* and not infrequently the interpretation of a given coefficient in terms of the former is difficult or impossible, even though after having observed all possible precautions we are convinced it is statistically significant.

Attempts at the determination of causes by statistical methods—e. g., by Bayes, Kapteyn, McEwen and Michael, and others—do not seem to have proved, in general, very successful; however, the results of recent investigations (*3*) seem to show that the theory of correlation gives promise of being able to effect a certain amount of progress toward the solution of this problem. The law of causality and the doctrine of uniformity, which constitute the foundation of all human knowledge, imply the complete and unique determination of each phenomenon by some definite complex of causes; our problem in any given case is to find what portion of the variation of some given quantity X'_0 is directly caused by (not merely simultaneous with) given variations in each of all the various quantities $X_1, X_2, \ldots$ influencing X'_0. The fundamental principles mentioned above imply the existence of some definite mathematical equation $f(X'_0, X_1, X_2, \ldots\ldots)=0$ which, if it could be found, would supply the solution of our problem. Probably all phenomena are determined by an indefinitely great number of causes; in the "exact" sciences, however, we deal with phenomena that involve a very few highly correlated variables together with a greater or less number of influences either negligible or else subject to control or elimination, and we can find, more or less easily, a mathematical function—"theoretical" (deductive) or "empirical" (inductive)—connecting the variables, that accurately expresses the phenomenon by an exact equation (at least over a certain range) except for the inevitable small "accidental errors" due to the neglected influences; but many natural phenomena are the result of the simultaneous action of a very great number of influences all of coordinate importance, mutually correlated in highly varying degrees, and difficult or impossible to isolate or control. For use under these latter circumstances, the methods of statistics have been devised, in which the concepts of contingency and correlation are substituted for those of causation and functionality. Of course, there exists every possible gradation between the two extremes (*4*).

Let

$$X'_0=f(X_1, X_2, \ldots\ldots, X_n, X_{n+1}, X_{n+2}, \ldots\ldots) \tag{1}$$

be the (unknown) complete and exact relation expressing a given phenomenon. Let M_i be the mean of X_i, and put

$$X_0=a_1X_1+a_2X_2+\ldots\ldots\ldots\ldots+a_nX_n+C, \tag{2}$$

where $C=M_0-\sum_{i=1}^{n} a_iM_i$. Then the actual, or observed, value will be X'_0, the value computed by (2) from the observed values of the X_i will be X_0, and the error of estimate will be X'_0-X_0.

Let $x_i=X_i-M_i$ be the departure, and σ_i the standard deviation, of X_i; and put $z_i=x_i/\sigma_i$. Then (2) becomes

$$x_0=a_1x_1+a_2x_2+\ldots\ldots\ldots+a_nx_n, \tag{3}$$

$$z_0=c_1z_1+c_2z_2+\ldots\ldots\ldots+c_nz_n, \tag{4}$$

where $c_i=a_i\,(\sigma_i/\sigma_0)$. The X_i may be mutually correlated in any manner, but the assumption will here be made that all relations are *linear*. The theory of linear partial correlation determines the a_i so that the sum of the squares of the errors of estimate is a minimum; the a_i then become partial regression coefficients—the regressions of X'_0 on the X_i when the remaining variables are held constant—and c_iz_i is the contribution of z_i to z'_0. The ordinary regression equation formed from a gross correlation coefficient gives the *average* value of one variable *associated* with any *particular* value of another variable: $\bar{x}_i=r_{ij}\;(\sigma_i/\sigma j)x_j$; thus *on the average*, for any given value of z'_0, the value of z_i is $\bar{z}_i=r_{0i}z'_0$; and Krichewsky (*3*) points out that therefore the successive terms on the right of

$$\bar{z}_0=c_1r_{01}z'_0+c_2r_{02}z'_0+\ldots\ldots\ldots\ldots+c_nr_{0n}z'_0$$
$$=z'_0\sum_{i=1}^{n} r_{0i}c_i\equiv z'_0\sum_{i=1}^{n} \mathrm{E}_{0i} \tag{5}$$

give the parts of the variation of X'_0 which *in the long run* are due to the fluctuations in each of the X_i. Krichewsky proves that $\Sigma\, E$ is equal to the *square* of the ordinary multiple correlation coefficient (correlation between X'_0 and X_0), which quantity therefore measures the exactness of (2); if (2) is exact and complete, $\Sigma\, E=1$ and $X'_0=X_0$.

If we adopt the square of the standard deviation, or *variance*, as a measure of variation "on the average", or "in the long run", then, as Krichewsky shows, the E_{0i} divide the variance of X'_0 among the causes in such a way as to supply fair and adequate quantitative measures of the extent to which each of the complete set of causes affects X'_0. An E may be either positive or negative; the *percentage of the variance* of X'_0 due to X_i is

$$\frac{|E_{0i}|}{\Sigma|E_{0i}|}. \tag{6}$$

It seems to the reviewer, however, that if in practise we find $\Sigma\, E_{0i}$ is not close to unity, then what (6) measures is not the percentage of σ'_0 due to X_i, but the percentage of σ_0 due to X_i—i. e., the percentage of that *part* of the variation of X'_0 which (2) takes into account.

The fact that for any two variables we may always write $x_i=r_{ij}\;(\sigma_i/\sigma_j)\;x_j+\epsilon$, where the mean of ϵ is zero, so

that $\sigma^2{}_i = r^2{}_{ij}\sigma_i^2 + (1 - r^2{}_{ij})\sigma_i^2$, does not permit us to hold X_j responsible for the share $r^2{}_{ij}$ of $\sigma^2{}_i$, *unless* X_j is completely independent of all the other causes of X_i, in which case, as Krichewsky shows, $E_{ij} = r^2{}_{ij}$; in this particular case, *Dines's law* holds, but if r_{ij} is the result of intricate intercorrelation between X_i and a number of mutually correlated causes, then $r^2{}_{ij}$ merely measures the *degree of covariation* between X_i and X_j; the measure of *causal connection* is E_{ij}. If *all* the X_i are mutually *independent*, and if (2) is *exact*, then $\sum_{i=1}^{n} r^2{}_{oi} = 1$.

The analysis of the variance of a composite variable by means of the E_{oi}, together with a careful study of the partial correlation coefficients, should be of material assistance in seeking a physical explanation for a series of gross coefficients and in evaluating the relative importance of different causal factors, although there still remains need for caution in drawing final conclusions, particularly (it seems to the reviewer) if $\Sigma E \neq 1$. In this connection, it is helpful to have at hand, for comparison purposes, the relations which hold in various special cases: For example, if three variables exactly satisfy the relation $x_1 = ax_2 + bx_3$, and if $r_{23} = 0$, then if the partial correlation coefficient actually accomplishes what it is supposed to, we should have $r_{12.3} = r_{13.2} = 1.00$; and it is a matter of simple, though somewhat cumbersome, algebra to show that this is the case (*5*); hence $r^2{}_{12}(1 - r^2{}_{12}) = r^2{}_{13}(1 - r^2{}_{13})$, from which, and the formulæ for the regression coefficients, $r_{12} = a(\sigma_2/\sigma_1)$, $r_{13} = b(\sigma_3/\sigma_1)$; then $E_{12} = (a^2\sigma_2^2)/\sigma_1^2$, $E_{13} = (b^2\sigma_3^2)/\sigma_1^2$; $\sigma_1^2 = E_{12}\sigma_1^2 + E_{13}\sigma_1^2$; $\Sigma r^2 = \Sigma E = 1$; and $z_1 = r_{12}z_2 + r_{13}z_3$. Again, if M_1 and M_2 are two effects of the cause A_3, $r_{12.3} = 0$, $r_{12} = r_{13}r_{23}$, $r_{13.2} = r_{13}$, $r_{23.1} = r_{23}$; this case has been discussed in some detail by C. F. Marvin in the preceding paper. If A_2, A_3 are the two causes of a result M_1, and are themselves correlated, $r_{12.3} = r_{13.2} = r_{23.1} = 1$. And so on.

As an illustration of how the above principles may be made to aid in the interpretation of correlation coefficients from the viewpoint of cause and effect, Krichewsky applies them to some of W. H. Dines's well-known coefficients; an extended investigation of this character would probably bring out clearly the physical implication of these coefficients and help appreciably in answering the many interesting questions raised by them.

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A STUDY OF THE POSSIBILITY OF ECONOMIC VALUE IN STATISTICAL INVESTIGATIONS OF RAINFALL PERIODICITIES

By DINSMORE ALTER

[University of Kansas, Lawrence, Kans., December 18, 1926]

In this series of papers embodying a systematic statistical investigation of the world's rainfall, an attempt has been made to refrain from all speculation and to present the evidence so far as possible from the viewpoint of mathematical probabilities of periods versus accidental relationships. For this reason both the causes and the economic value have not been mentioned beyond the briefest discussion several years ago.

It seems wise, however, at the conclusion of the work to make an attempt to learn whether the periodicities found have only a purely scientific interest, or in addition, a possible economic value. Such a value could at the most only pretend to divide seasons in advance into wet, normal, and dry, where wet is defined as including all which average among the wettest third of the data, dry those among the driest third, and normal the remainder. On the basis of accident such predictions should be fulfilled one time out of every three. The work done indicates that *in the long run* such predictions almost certainly can be made with at least a slight increase over this fraction. However, unless the increase is rather large they will have no interest save a purely scientific and statistical one over many years.

To be conclusive, such an investigation must do two things:

(*a*) It must examine the data already available, in order that we may know the percentage of times the periods found will represent the data used in finding them, to this accuracy.

(*b*) It must make *test* predictions that we may follow them through the future and thus weight their value. It is certain that in the long run these can not be fulfilled as accurately as the past representations, for the accidental errors are certain to have modified, more or less, the periods found. In addition, periods of greater or shorter length will have an effect.

It is very important to note that even if we had data which were entirely free from accidental errors and from periods other than those obtained and used in prediction, and even though we knew perfectly the magnitudes and phase relationships of these periods, they would not correctly predict the means for a given stretch of time. In two of the papers of this series, the effect of the datum interval on the magnitude of the amplitude has been investigated and a factor F determined by which multiplication is necessary in order to reduce the amplitude or the intensity found, to what it would have been had much shorter intervals been used. When we have the reverse problem it is necessary that we divide by this factor before predicting. If the predictions are to be made for the same interval used in the original periodogram the factor is eliminated. If not, we must multiply the amplitude obtained from the periodogram by the F corresponding to that ratio of period length to datum interval and divide by that of the ratio to the predicted datum interval. If we do not do this, short periods will exert far too great an influence on our predictions and cause them to fail. In the present preliminary paper, where

we are interested not in obtaining the theoretically best predictions possible, but merely in an approximation to them, we shall find that the factor F is only a criterion of length of the periods short enough to be neglected in predictions of means. For such amplitudes as have been found, we shall use about three times the datum interval.

This is six months; therefore we can neglect periods of shorter length than one and one half years. Of course, if a period of length *greater than one year* and of tremendous amplitude with respect to those of the longer periods had existed, it would have been necessary for us to use it, although with extreme caution.

When we examined the periodograms from the halves of the data (MONTHLY WEATHER REVIEW, February, 1927), we found that the correlation in the case of the British Isles was very much higher than in the other cases. Obviously, therefore, whether it may finally prove valuable to predict for any one or all of these sections, our chances of success are far better here than in the other cases. Since the present predictions are not made for actual agricultural use nor even for the purpose of finding whether the rainfall of a given section is predictable but to find whether that of *any* section is so, to an extent which makes it economically valuable, it seems best to confine our study to this one section. If it should prove worth while, these other sections and of course many more must come up for investigation.

In the last paper we showed that the correlation between stretches of the actual rainfall observations separated by 43 years is 3.50 times its probable error and has an expectancy ratio of one in 1,100. Since there were 64 pairs of data to compare we can be quite certain that this is not the result of accident. It may be noted in passing that this relationship is entirely independent of the periodogram or of any theoretical discussion. *It is a matter of actual observation.*

Turning now to the periodograms (this REVIEW, *loc. cit.*) we find that almost without exception the peaks found, even the rather low ones, are through the whole stretch of periods from one and one-sixth to nine years very closely harmonics of a period slightly in excess of this value. This is to be expected after we have found such a high correlation in the data themselves. They of course indicate that if we had compared data with those a trifle more than 43 years later, instead of exactly 43 years, a higher correlation could have been found. We should note that these values were obtained from 75 year's data, a number in no way simply related to 43 years or to 43 and a fraction, and hence in no way open to the objection of being a mere mathematical Fourier series representation.

There are two obvious methods of making our test predictions, each with its advantages and disadvantages. The simpler is to record the data as they occurred 43 years before the predicted date. This is of course very easy to do and to weigh. The other method is to choose those terms which have large amplitude in the periodograms and to combine them, representing both past and future by them. The advantages and disadvantages are:

(*a*) Any small real harmonics of 43 years which are used in the extrapolation, but neglected in the analytical method, improve the predictions by the comparison method.

(*b*) In comparing data themselves, the accidental errors enter into both the old and the new values in such a way that on the average they will produce a discrepancy the $\sqrt{2}$ times as large as in either. If we select only those periods of large amplitude for our work, we shall to a great extent obviate this difficulty.

Which of these two is the better to use for prediction of wet, normal, and dry seasons can not be stated until after a representation has been made by each. First we shall see the results obtained by extrapolation.

In obtaining our correlation coefficient between actual data separated by an interval of 43 years, 64 pairs of values were used. Of these, 38 pairs were either both above or both below normal, three had one value exactly normal and only 23 were of the opposite sign. Excluding the three cases where one value was normal, as being neither an agreement nor a disagreement, we find that the past representation holds 62 per cent of the time and fails 38 per cent. Unlike the case of the analytic representation, it is reasonable to hope that past and future may hold equally well. If so we would be here on the border line of value for economic uses.

It is more useful to consider three groups instead of two. One-third of the data fall in a group 92 to 108 per cent of normal, inclusive. A third fall below 92 per cent and a third above 108 per cent. We find that twenty-eight times out of the sixty-four both values of the pair fall in the same group, a percentage of 44 instead of the 33 expected through accident. It is reasonable to suppose that the pairs containing the oldest data have larger accidental errors than the others. If we consider the latter half of the 64 pairs we find 18 pairs out of 32 in the same group, a percentage of 56 instead of the accidental 33. Quite possibly our correlation would have been higher had we not had larger errors in the 1850–1865 data than in the others. This is quite plainly indicated by the fact that the sum of the squares of the residuals from the normal is largest for these years, although quite evenly balanced between positive and negative values. The larger errors of the earlier data are to be expected not only because of probably less accurate observations but also because we used only three stations instead of five, as in the later part. Possibly we would have improved the correlation had we formed new 6-month means of the second stretch of data, making them fall 43 years and 1 month after the earlier. It does not seem worth while to do it now, for the probable improvement would scarcely affect the decision regarding the test predictions. If predictions for agricultural use were to be made we should, of course, improve them by every such means, even though the gain be slight. The data used end with 1924, therefore the predictions given as Table 1, begin with 1925. They are carried through 1936. If these are fulfilled there will be considerably fewer wet years than we usually have.

In the case where the peaks of the periodograms fall so close to the Fourier harmonics, it seems well to try forcing the curve to the 43-year period shown independently. If we find that a small number of the harmonics represent the dat quite accurately, we shall prefer to use them in making test predictions because of the more balanced manner in which the accidental errors enter. If, on the other hand, many terms are required, we shall use the extrapolation as the method which is probably the more accurate.

Prof. Dayton C. Miller, of Case School of Applied Science, was kind enough to determine the first 30 harmonics of the 43-year period by his harmonic analyser. This new determination was necessary because of the slight discrepancies between periodogram peaks and harmonics, which made some shift in amplitudes and phase relationships.

In order that all the data might be used, values separated by 43 years were averaged. Since the phase relationships must be identical under our hypothesis,

such a procedure is certain to give more satisfactory results. They were then plotted as a curve 400 millimeters long.

Twenty of these harmonics showed amplitudes large enough to indicate possible reality. This fact alone indicated clearly that the correlation found was due to many terms. However, a synthesis was made from the eight largest terms. It was no better than that made by extrapolation and, therefore, no predictions are tried from it. Of course all the harmonics could be used for a synthesis which would represent *past* data more accurately than was done.

Seventy-five years' data were used. It may be possible to secure data taken before 1850 sufficiently accurate to use. Eleven years of such data would make it possible to extrapolate from averages of two datum values. If not, the 43-year period will be completed twice by the end of 1935 and any accuracy which may be found for predictions now should be materially increased after that date.

It is quite probable that for any one of three causes the length of the 43-year term may shift as time goes on. These causes have been thoroughly discussed in the previous papers and need only be mentioned here.

In conclusion, a period approximately 43 years, with harmonics, exists in the rainfall data of the British Isles. It may be complex, it may be constant, and it may be variable; time alone can tell which of these is true. Whether predictions made by it at present, or even at some future time, can have economic value is uncertain. However, the chances are sufficient to warrant the attempt, if it be sufficiently emphasized that the predictions are for test purposes only.

About half of the computations for this paper were made under a grant from the Research Committee of the Graduate School of the University of Kansas. I wish also to express my thanks to Professor Miller for the analysis made by him. Without that aid, part of the contemplated work would have remained incomplete on account of lack of time.

TABLE 1.—*Test predictions for British Isles rainfall through 43-year extrapolation*

[A indicates first half of the year, B the second half. Wet, normal, and dry as defined in body of the paper]

	Data A	Data B		Data A	Data B
1925—A	Wet	Wet.	1931—A	Dry	Dry.
B	do	Do.	B	Normal	Normal.
1926—A	Normal	Dry.	1932—A	Dry	Do.
B	do	Normal.	B	do	Do.
1927—A	do	Do.	1933—A	Normal	Dry.
B	Dry	Wet.	B	do	Normal.
1928—A	Normal	Dry.	1934—A	Dry	Do.
B	Dry	Do.	B	Wet	Wet.
1929—A	Wet	Wet.	1935—A	Dry	Dry.
B	Normal	Normal.	B	Normal	Normal.
1930—A	Dry	Dry.	1936—A	Dry	Dry.
B	do	Do.	B	Normal	Do.

ADDENDUM

The additional data received in January, 1927, from the Chief of the Weather Bureau gives two complete 46-year cycles. As a result, predictions should be more accurate, although the probable inaccuracy of observations made nearly a century ago is so great that the gain can not be much. The predictions from the original data are given in the table under Data A, those from the more complete record under Data B. Sixteen predictions are unchanged among 24. Most of the changes are merely shifts across the dividing line between adjacent groups. In only one case, the latter half of 1927, is there any serious shift. For this epoch a prediction, which barely missed being normal, is shifted from dry to just outside of the normal group on the wet side.—*D. A., February 18, 1927.*

THE THUNDERSTORM AT CINCINNATI AND ITS RELATION TO ELECTRICAL POWER SERVICE

By W. C. DEVEREAUX

[U. S. Weather Bureau, Cincinnati, Ohio]

NOTE.—Ninetieth meridian time is used in this article, including the tables and charts. Seventy-fifth meridian time was adopted for Cincinnati by the Weather Bureau on January 1, 1927.

During the 11 years that the Abbe Meteorological Observatory has been maintained in Cincinnati, a most careful and detailed record of all the weather elements has been made. The thunderstorm, like the clouds, must be observed and described by trained observers—no instruments have been devised that will fully meet the requirements or take the place of scientific training. The average recorded number of days with thunderstorms at Cincinnati in the last 10 years shows an increase of 23 per cent as compared with the previous 10 years, due to improvement in the location of the place of observations, and in the methods of observation.

In this study of the individual thunderstorm it is necessary first to define the thunderstorm. Alexander, in his article on the distribution of thunderstorms, has quoted all the instructions to observers on the subject—the last one was issued in January, 1894—and stated that the instructions have been in force ever since. About the only instruction in force at present is that "a storm from which distinct thunder is heard will be considered a thunderstorm," while the instructions to cooperative observers add that "thunderstorms six hours apart may be considered as separate storms."

It is unusual for an individual thunderstorm to last more than two hours, while on the other hand several may occur within one hour. Frequently two or more separate thunderstorms may be visible at the same time. One summer evening distant and diffused lightning was observed in the north for about one hour after dark, then thunder was heard in the north and the separate lightning strokes became visible; other storms started in the west and southwest, until at one time four separate parts of a general storm were visible and thunder could be distinctly heard from each cloud mass—one in the northeast, one in the north, one in the northwest, and one in the west—all storms moving northeastward. Up to this time no rain had fallen at the station, but the next storm, which developed to the southwest, moved directly over the station, and the series of storms that evening were ususually severe. While these storm clouds were separated by a considerable distance, and the path of each was a few miles south of the preceding one, they acted together, and therefore the series should be considered a single thunderstorm. At other times we have observed two or three distinct storms in progress at the same time when there appeared to be very little, if any,

physical connection between the clouds; these should be considered as separate storms.

Recently while traveling directly eastward by automobile from Cincinnati 150 miles, we passed along a line where a large number of thunderstorms developed. The sky continued mostly clear to the south, while in the rear, thunder would be first heard in a comparatively small cloud and the storm would pass rapidly north of us, moving to the northeast. Some were attended by rain. These storms developed eastward at the rate of 20 miles per hour, but the individual storms moved at an estimated rate of 40 miles per hour.

In this paper a thunderstorm will be defined as "a commotion in the atmosphere in which thunder is heard, each separate cloud mass attended by thunder to be considered an individual thunderstorm." The smallest thunderstorm observed at Cincinnati was on a clear, summer day. A small thin cloud formed in the southwest, and, as it moved directly toward the station, one dull peal of thunder was heard, after which the cloud dissipated as quickly as it had formed.

Our principal object in this paper is to show the variation in frequency of occurrence of the thunderstorm during each of the 24-hour periods at Cincinnati. Much has been written about the physical aspects of the thunderstorm, the annual and monthly variation, and the geographic distribution, but comparatively little about the daily variation. The principal exception is in Cox and Armington's "Climate of Chicago." Most of the authorities, as Ferrell, Davis, Ward, Humphreys, Alexander, and others state that thunderstorms are most frequent during the afternoon, but have little to say about the other hours of the day.

For study purposes, we entered on large sheets of cross-section paper all the data about each thunderstorm for the last 20 years, using one sheet for each month, except for the winter months, which were placed together on one sheet. On these charts were shown by symbols or figures the time and duration of each storm, the time of rainfall, the rate of heavy and excessive rains, the direction of movement, the type of the storm, and other information. As these charts were much too large to reproduce, two other and much smaller charts for 10 years have been prepared to show only the time and duration of thunderstorms. The third chart shows by vertical bars the total hours with thunderstorms for each hour during the year for a period of 20 years; the fourth one, the hourly variation by seasons, and for July, the month of greatest frequency.

In hourly frequency as well as i tensity the thunderstorm is naturally divided into four types or seasons, but the seasons differ somewhat from the seasons of the year. The summer type, which comprises about 8 per cent of all thunderstorms at Cincinnati, begins in May or sometimes late in April and usually ends about the last of August or early in September. During this season the stormiest hour is from 2 to 3 p. m., when the temperature is highest, and the least stormy is the hour ending at either 9 or 10 a. m., not at night or when the temperature is lowest, but during the hour of most rapid rise in temperature. In the month of greatest frequency—July—there have been 63 thunderstorms in 20 years for the hour ending at 3 p. m. and only 4 for the hour ending at 9 a. m. The fall thunderstorm, which occurs in September and sometimes in October, reaches a maximum about 3:30 p. m. and a minimum at 11 a. m. Both the summer and the fall thunderstorm appear to have a second maximum about 6 a. m. but this is probably due to a failure to record all thunderstorms between midnight and 6 a. m. The spring thunderstorm, during March and April, occurs most frequently during the afternoon,

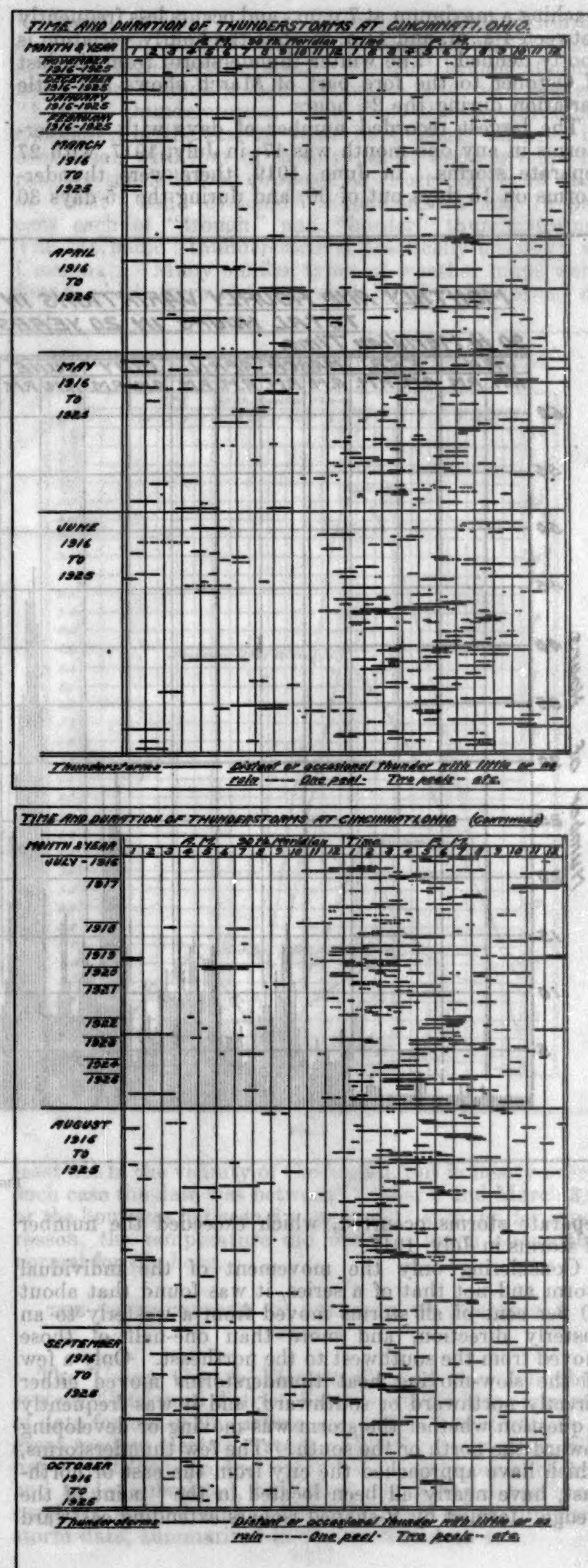

FIG. 1

reaching a maximum at 7 p. m., and occurs less frequently between 4 a. m. and 11 a. m., but the hourly variation is poorly defined. The winter thunderstorm from the last of October to the fore part of March shows but little variation during the 24 hours.

The largest recorded number of days with thunderstorms in any one month was 17, in July, 1917, with 27 separate storms. In June, 1919, there were thunderstorms on 15 days out of 30, and during the 15 days 30

from a low center over Missouri or the extreme lower Ohio Valley, with comparatively high pressure both north and south of the station. During 10 years of detailed record at the Abbe Meteorological Observatory no thunderstorms have been observed moving from the southeast to the northwest.

The tendency of all thunderstorms to move eastward is very pronounced, even under what appear to be adverse conditions.

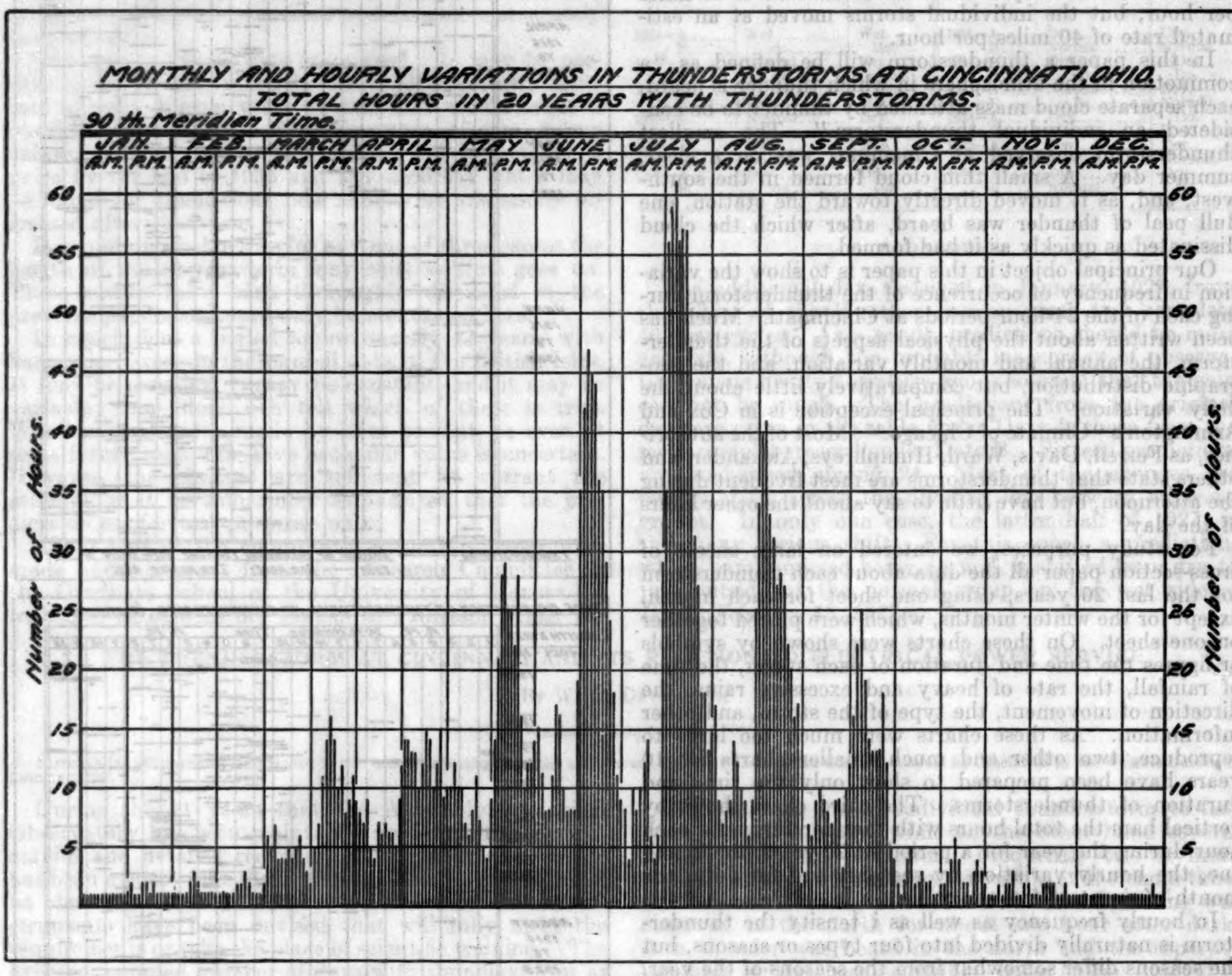

FIG. 2

separate storms occurred, which exceeded the number of storms in July, 1917.

Considering only the movement of the individual storm and not that of a series, it was found that about 90 per cent of all storms moved from a westerly to an easterly direction, and more than one-half of those moved from the southwest to the northeast. Only a few of the slow-moving heat thunderstorms moved either directly northward or southward, and it was frequently a question whether the storm was moving or developing toward the north or the south. The few thunderstorms, which have approached the city from the east or northeast, have nearly all been located in the "point of the wedge" formed by V-shaped isobars extending eastward

Storms have been observed to move eastward against high strato-cumulus clouds moving from the east, and across fresh southerly winds. A few of the storms move with great rapidity, especially when associated with a rapidly moving LOW, but the surface wind is seldom over 30 miles per hour. In one storm thunder was first heard in the far southwest, and last heard in the far northeast 15 minutes later. If each of these peals was 10 miles from the station, the storm must have moved at the rate of 80 miles per hour. The highest surface wind in this storm was 25 miles per hour. The "heat" and "border" thunderstorm, and the thunderstorms in the "trough" are usually slow-moving storms, and frequently the most destructive.

Of the 340 thunderstorms that passed either north or south of the Abbe Observatory during the last 10 years, 200, or 60 per cent, of them passed north and only 40 per cent passed south of the station. South of the observatory is the central portion of the city with a great network of wires and many high buildings, but all located in the valley of the Ohio River; while north of the station is higher land with mostly open country except for a small thickly settled valley near-by, which, however, is sheltered by a ridge of hills on the west. Out of 213 storms charted for July, the month of greatest frequency, 52 passed over the station, 86 north of it, 40 south of it; of the remaining 35, a few passed either east of west of the station, but most of them were distant thunderstorms without apparent movement. In a recent paper on "Thunderstorms in the British Islands" the statement was made that, "In America the summer storms (thunderstorms) occur very largely along the main valleys," and similar statements have been made by other meteorologists, but the conditions do not appear to be true for the middle Ohio Valley.

The occurrence of thunderstorms and the variation in the time of occurrence depend on the meteorological factors and the time elements. The two most important weather elements are the distribution of pressure and the temperature of the air—and the two equally important time elements—the time of the year and the hour of the day. Each of these may be divided into three phases of favorableness to thunderstorm occurrence—the maximum, the intermediate, and the minimum phase. The maximum phase of pressure distribution is a LOW northwest of the station and higher pressure to the south, the intermediate is when the weather map is "flat," and the minimum is when the pressure is high north of or over the station. The maximum phase of temperature is temperature considerably above the normal for the hour, the intermediate is normal temperature with high humidity, and the minimum is temperature low for the hour. In the time elements the maximum phases are May to September and between the hours of 11 a. m. and 8 p. m., the intermediates are the early spring and late fall months and the hours from 8 p. m. to 8 a. m., and the minima are the months from November to February and the hours between 8 a. m. and 11 a. m. throughout the year. When the four maximum phases are in conjunction the thunderstorm develops, when some of the intermediate phases occur with the maximum phases the thunderstorm frequently develops, but when two or more minimum phases are in the series the storm does not develop. Other weather elements are factors of some importance in producing thunderstorms, but these, as well as temperature, are connected with and result from the pressure distribution. When the thunderstorm develops, the LOW is nearly always present to the west, northwest, or north of the station, but is often poorly defined and apparently shallow. These rules, if they may be so named, apply best to the last half of the day during the summer months. The occasional winter thunderstorms and those occurring after midnight obey few if any evident rules.

Doctor Humphreys in the MONTHLY WEATHER REVIEW for June, 1914, presents five types of weather maps attended by thunderstorms. These types and thunderstorms which attend them are defined briefly as: *a*, Regions of high temperature and widely extended and nearly uniform pressure, "heat" thunderstorms; *b*, the southeast quadrant of a LOW, "cyclonic" thunderstorms; *c*, the barometric valley between the branches of a V-shaped cyclonic isobar, "tornadic" thunderstorm; *d*, the region covered by a low-pressure trough between adjacent high-pressure areas, "trough" thunderstorms; and *e*, the boundary between warm and cold waves, "border" thunderstorms. The 1,500 thunderstorms at Cincinnati in the last 20 years have nearly all been in connection with four of these types of weather maps in roughly the following proportions: Forty per cent each of "heat" and "cyclonic" thunderstorms and 10 per cent each of "trough" and "border" thunderstorms. The "tornadic" thunderstorm is practically unknown at Cincinnati. Many similar types of weather maps were found which were not attended by thunderstorms, at least not in the vicinity of Cincinnati, but in nearly every such case the date was between October 1 and March 31, or the hour was between 8 a. m. and 11 a. m. or, for some reason, the temperature did not rise much above the normal for the hour.

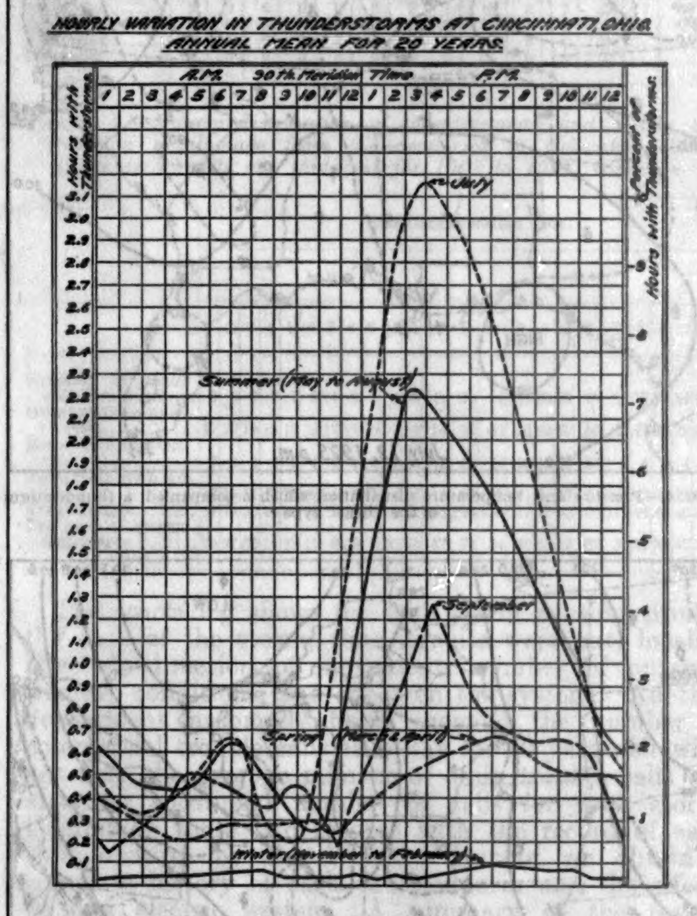

FIG. 3

THE THUNDERSTORM IN RELATION TO ELECTRICAL SERVICE

The Union Gas & Electric Co., of the Columbia system, Cincinnati district, has prepared a large amount of data for use in this article, on the effect of storms on a great modern electric system. Unfortunately space will not permit the reproduction of the large number of charts and tables submitted, but all of the material has been carefully studied and the results, with other thunderstorm data, summarized in Tables Nos. 1 to 4.

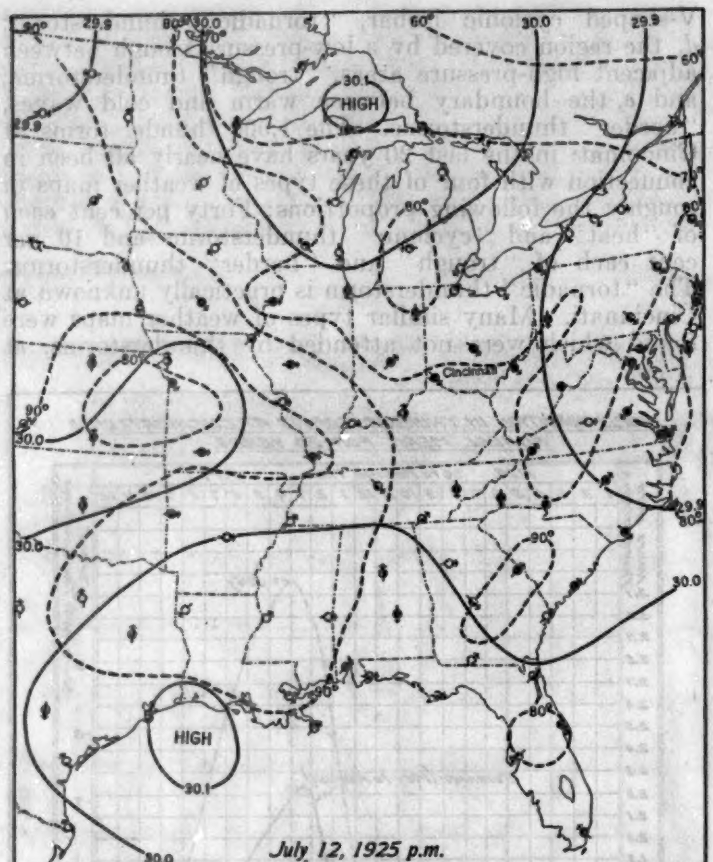

FIG. 4.—Pressure and temperature distribution which accompanied a thunderstorm of the "heat" type

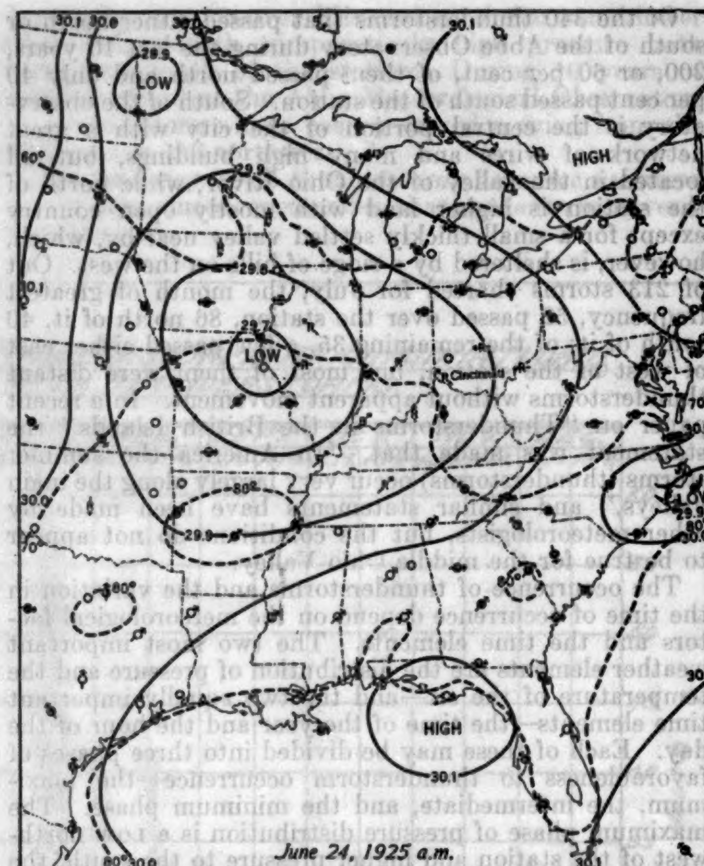

FIG. 5.—Pressure and temperature distribution which accompanied a thunderstorm of the "cyclonic" type

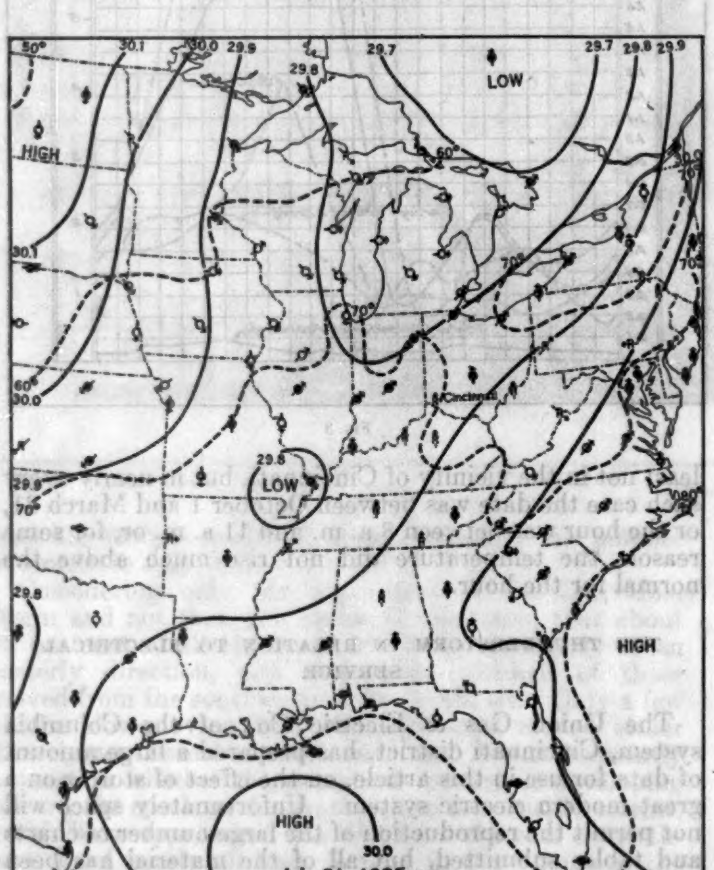

FIG. 6.—Pressure and temperature distribution which accompanied a thunderstorm of the "trough" type

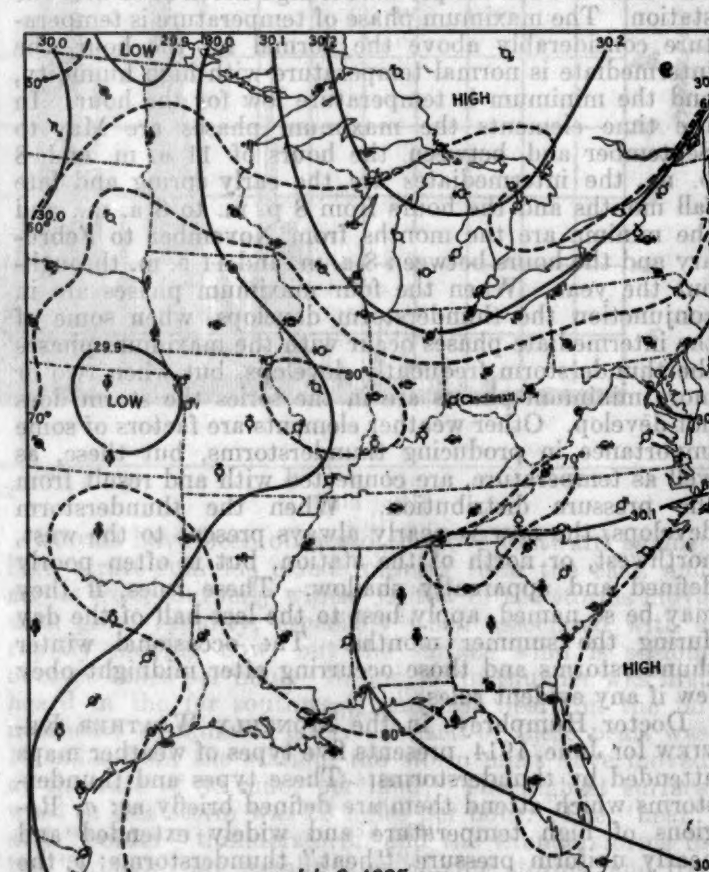

FIG. 7.—Pressure and temperature distribution which accompanied a thunderstorm of the "border" type

The remarkable features of the tabulations are the great growth of the electric service in the Cincinnati district during the last 10 years, and more especially during the last five years; the great increase in the amount of damage by thunderstorms to the electric system. The wind when not attended by a thunderstorm occasionally causes considerable damage, but in a region where the maximum wind velocity seldom exceeds 40 miles per hour, and exceeded 50 miles only two times in 10 years, the damage caused by the wind alone is not great. The sleet, snow, and other similar elements are minor agents of destruction to the electric system.

A "storm log" was prepared by the department of operation of the Union Gas & Electric Co. for the years 1921 to 1926, inclusive. It was difficult to obtain the information for the years 1921 to 1923, and as there were comparatively few overhead circuits in operation previous to 1921, the report was not extended back to 1917. The report for 1921 shows that the amount of trouble was comparatively small and the number of outages listed does not give a true idea of the number of storms. For that reason the report for 1921, though included in Tables Nos. 1 and 2, showing the growth of the system, is not included in Tables Nos. 3 and 4, showing the effect of the storms.

TABLE 1.—*Growth of the Columbia electric system in the Cincinnati district*

NUMBER AND MILEAGE OF OVERHEAD CIRCUITS IN SERVICE AND NUMBER OF CONSUMERS 1921 TO 1926

Year	4,325 volts	13,200 volts		33,000 volts		66,000 volts		Total except 4,325 volts		Commercial consumer	Total area (square miles)
		Number	Miles	Number	Miles	Number	Miles	Number	Miles		
1921	(1)	7	26	6	87	0	0	13	113	64,429	236
1922	(1)	7	32	7	94	0	0	14	126	77,292	------
1923	(1)	8	37	9	132	3	48	20	218	93,466	------
1924	(1)	14	54	9	147	4	71	27	271	107,425	------
1925	(1)	16	58	9	151	14	171	39	381	119,363	------
1926	(1)	21	71	11	147	14	171	46	389	127,439	270

[1] No data available.

TABLE 2.—*Damage from storms, by years, to Columbia system, Cincinnati district*

Year	Days with thunderstorms	Destructive storms		Total time of outages		Number of circuits out			Commercial trouble calls	
		All storms	Thunderstorms	h.	m.	All storms	Thunderstorms	Maximum in 1 thunderstorm	Average daily for the year	Maximum for 1 thunderstorm
1921	77	13	13	29	49	43	42	12	46	160
1922	53	31	15	48	32	98	80	11	54	185
1923	42	24	19	65	33	124	96	11	81	290
1924	50	43	15	167	3	537	327	55	91	445
1925	58	46	34	141	24	522	453	53	110	715
1926	57	46	30	304	42	754	645	105	116	1,060

TABLE 3.—*Storms and circuits out by months, Columbia system, Cincinnati district*

Month	1922—Destructive storms			1923—Destructive storms			1924—Destructive storms			1925—Destructive storms			1926—Destructive storms		
	All classes	Thunderstorms	Outages	All classes	Thunderstorms	Outages	All classes	Thunderstorms	Outages	All classes	Thunderstorms	Outages	All classes	Thunderstorms	Outages
January	0	0	0	2	0	5	1	0	4	3	0	12	4	0	16
February	1	0	3	0	0	0	1	0	15	3	0	35	3	0	32
March	4	2	17	3	1	22	5	1	100	5	4	17	0	0	0
April	4	4	13	1	0	1	5	2	44	6	6	26	3	1	15
May	4	4	10	2	2	7	5	4	34	4	3	27	5	5	195
June	1	1	4	2	2	12	8	8	162	6	5	59	7	7	147
July	4	4	7	8	8	40	4	4	39	9	9	254	8	8	227
August	10	8	38	6	6	37	6	5	58	5	5	41	6	4	136
September	3	2	6	0	0	0	2	1	16	2	2	32	7	5	47
October	0	0	0	0	0	0	1	0	64	1	0	1	3	0	45
November	0	0	0	0	0	0	2	0	8	2	0	18	----	----	----
December	0	0	0	0	0	0	3	0	21	0	0	0	----	----	----

TABLE 4.—*Hourly distribution of thunderstorms and hourly distribution of damage from thunderstorms to Columbia electric system in circuits out (outages) for 1922 to 1926, inclusive*

	Ninetieth meridian time																							
	A. M.												P. M.											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Number of hours with first thunder	9	6	7	7	7	9	11	8	4	4	6	21	25	24	28	30	20	26	22	13	19	10	10	8
Hours with thunderstorms	17	20	19	13	12	14	17	18	10	7	8	24	34	42	53	58	57	56	53	43	35	28	28	17
Hours with first outages	7	4	4	1	2	1	0	4	0	2	2	12	18	13	10	13	15	16	7	4	6	4	2	6
Total hours with outages	13	13	11	10	10	10	6	7	4	4	4	15	27	37	41	45	47	53	46	42	33	23	12	7
Total outages	67	73	39	16	16	9	2	19	6	16	11	163	223	156	117	75	92	107	112	84	49	40	37	74
Per cent of storms destructive	78	67	56	14	28	11	0	50	0	50	33	57	72	54	36	43	75	62	32	31	32	40	20	75

The storm log shows for each storm causing trouble the date of the storm, time circuits were out, locality affected, direction of movement, number of outages, weather conditions, and effect on the system. Another department prepared charts showing the number of commercial trouble calls each day for 10 years, showing not only the average number of daily trouble calls but also the additional number of calls for each storm. Combining these two records with the record of each thunderstorm by the Weather Bureau we obtain a complete history of each thunderstorm and the effects on the electric system. A summary of the results obtained is shown in the tables. In using the tables, especially in comparing the number of outages and trouble calls in 1921 or 1922 with later years, as shown in Tables Nos. 2 and 3, allowance must be made for the growth of the system, as shown in Table No. 1, under number and miles of overhead circuits and number of commercial consumers. During the same period the area covered by the overhead circuits has increased from 236 square miles in 1921 to 270 square miles in 1926.

In addition to the information contained in the tables, the storm log shows interesting details of the damage from the thunderstorm under the "effect on the Columbia system." In 1921 and 1922 the damage consisted entirely in putting out of commission the 4,325 volts, 13.2 kilovolts, and 33-kilovolt lines. The 66-kilovolt lines were constructed in 1923, but were not in operation until the end of 1925. In 1922 and 1923 in addition to the various circuits being out, trouble was also experienced in flashing of insulators, causing bad potheads, hot crosses, and burning out rotary converters.

"Surges" became a prominent source of trouble from the thunderstorm late in 1924, and continued to cause much trouble the two following years. Surges are the dropping of the load on a high-tension line, such as 33 kilovolts, to say, 15 kilovolts, a rise above 33 kilovolts, and then a drop again. This kicks out the circuit. During the year 1925 surges during 10 of the 34 destructive thunderstorms caused 184 outages and probably several more.

Storms during these years apparently caused considerable trouble with arc circuit and direct-current machines. In the storm log no mention is made of machines being out until April 24, 1926, when the following appears: "Six outages on 66-kilovolt circuits and 5 machines out due to surges." During the remainder of 1926, there were 96 machines out in 17 thunderstorms. This was the first full year of service from the Columbia station, located on the Ohio River 20 miles below Cincinnati, with 171 miles of high-voltage lines transmitting current. Other causes of trouble mentioned most frequently during the last year were: Poles on fire, hot crosses, arc circuits out, and lightning arresters hit.

The area of observation of thunderstorms at the Abbe Meteorological Observatory is practically the same as the area covered by the network of the Columbia system at Cincinnati. The frequency and intensity of the storms as observed have been compared with the damage to the electric system. The electric-power company is only one of the industries affected by the thunderstorm, and similar industries suffer corresponding losses throughout the region of thunderstorms.

CAN THUNDERSTORMS BE CLASSIFIED?

ALFRED J. HENRY

The Editor is moved to these remarks by the classification of thunderstorms given by Mr. Devereaux on p. 115.

Scientists are perhaps never so well satisfied with their efforts as when they have succeeded in classifying some particular phenomenon that hitherto had escaped the hands of the classifier. Classification is common to practically all writers on scientific subjects. First, they observe and then they sort into groups or classes those objects which have one or more features in common, and by this method they arrive at "genera" and then "species," and so on. In the biological sciences such procedure is logical and helpful since the difference between any two classes of objects is significant.

When, however, one attempts to class thunderstorms he must sooner or later discover that about the only thing they have in common is their dependence as to origin on atmospheric instability, however that is brought about.

It has been recognized for many years that one of the two so-called types of thunderstorms, "heat" and "cyclonic" shades imperceptibly into the other and that it is not practicable to distinguish between them.

This was recognized by Mohn and Hildebrandsson, who were probably the first writers to class thunderstorms into two main groups as above indicated. These authors expressly say: "However, it is in Sweden impossible to find a well-defined boundary between these two classes of thunderstorms." [1]

Hann and Süring in the former's well-known Lehrbuch, follow Mohn and Hildebrandsson and add a third group, viz, those which originate along the borders between warm and cold areas. This class was not named.

It is but natural that further study of thunderstorm phenomena should disclose a greater variety of conditions of origin than has hitherto been recognized, especially if, as Humphreys has done, the form of the isobars at or very shortly after the occurrence of the thunderstorm be made the criterion of classification. Humphreys, as stated by Devereaux, describes five classes, viz, heat, cyclonic, tornadic, trough, and border. The two first named and the last named have already appeared in the literature.

Any classification to be useful should be adopted by the majority of organized weather services; pending such adoption it would seem to be preferable not to stress the grouping by classes, remembering that to the man on the street a thunderstorm is a thunderstorm and nothing more; moreover, there do not seem to be any well-recognized differences between thunderstorms that could be used as criteria for classification.

[1] Les Orages dans la Peninsule Scandinave. Upsala, 1888.

WEATHER AND FOREST INFLAMMABILITY IN THE SOUTHERN APPALACHIANS [1]

By E. F. McCarthy, Silviculturist

[Appalachian Forest Experiment Station]

FOREST FUELS AND THE FIRE SEASONS

The Appalachian forest, composed largely of deciduous species, creates a fire hazard over its entire area through the annual fall of leaves. Even the pines, and to a lesser extent the other coniferous species, add each year to the amount of litter upon the ground.

The seasons of inflammability are generally limited to the spring and fall, when there is neither a cover of snow to check the drying of the forest floor nor a protective cover of green vegetation. Fires occur but are not prevalent during the winter season, and are rare in the summer, but sometimes occur in exceptionally dry seasons. During the spring and fall the leaf litter is exposed to rapid drying through the effects of sunshine, dry atmosphere, and winds.

The presence of a quantity of litter on the ground is the primary requisite for a fire hazard, and this is most pronounced in the fall when the new crop is all down and has not yet become settled or compacted through the beating action of rains and snow. In the spring this crop of leaves is more compacted, but has not decayed enough to reduce appreciably the total amount of inflammable material. During the summer disintegration goes on rapidly, and by the succeeding fall the hazard is much reduced until the new crop is down.

Grass and other annual or biennial vegetation is most important on forest land recently cut over or partially stocked. Similarly, hardwood slash is not a primary hazard but serves to intensify the heat of fires carried largely by other fuels. Both of these conditions are very subordinate in point of area to the leaf-litter hazard.

Leaf litter is extremely sensitive to changes in atmospheric moisture; in fact, it may be dampened to a condition of low hazard without rain through the action of dew and frost in times of high humidity. In rare periods fire will run briskly through the night, but normally day is the time of hazard.

STORM MOVEMENT

Fire hazard is directly associated with the weather, and has a definite place in the usual cycle of storms. In this region it is associated with the weather of the anticyclone. The region is so situated that a wave of low pressure can scarcely pass across the continent without bringing at some time a period of southerly or easterly winds to the region. These, coming from the direction of the Gulf of Mexico or the Atlantic, tend to increase the atmospheric moisture. The period of highest hazard is that of low relative humidity, and is limited to times of continental winds from the west and northwest, or periods of calm when air pressure is high over the Appalachian region.

There comes regularly in the cycle of storms a change of wind from the south and east to winds from the west and northwest, as the LOW center passes to the east, and the masses of polar air advance behind it. The character of this wind shift will, of course, be determined by the path of the storm, whether to the north or south of the region in question.

The fact of importance from the fire standpoint is that after each storm the wind shifts from its ocean and Gulf sources to a continental source. This shift brings colder air that is not only dry from its source, but becomes drier as it warms on its southerly course and as it settles to lower elevations. With the shift of wind come higher air pressure, lower temperature, and lower absolute moisture content of the air. It is a time of fair weather.

The series of conditions which follow the passage of a storm are clearly discernible from the records of the Weather Bureau taken each day and mapped for the central part of the continent. For the Appalachian region, changes coming from the west in the condition of the weather can in a general way usually be foreseen for a period of three days, and from the southwest for a period of at least 36 hours. Within these limits forecast of dry periods can be made more certainly than for storms, and adjustments may be made in the disposition of the forest protective forces. Well organized forest protection forces can utilize the regular forecasts of the Weather Bureau, which are approximately for a 36-hour period. Beyond this, a knowledge of the usual sequence of the weather gained through visits to a station where daily maps are available will make possible forecasts for even longer periods. Proficiency in making such forecasts beyond the usual 36-hour period will depend upon familiarity with the usual courses of the storms as they cross the continent, with their rate of travel, and the influence of the cyclonic disturbance on precipitation, atmospheric moisture, wind, and temperature. Much more than the mere prospects of precipitation can be learned from the study of the daily weather map.

Changes in temperature, wind, and humidity are likewise important and can be forecast to some extent.

Figure 1 illustrates the correlation between the several factors of weather and the occurrence of fire, and clearly indicates the weather which attends a period of inflammability. This is the graphic representation of the conditions during the fall fire season of 1922, including current fires, which are shown by dots on graph 4.

Rains (graph 2) occurred at times of low air pressure (graph 5). With the increase in air pressure there occurs a drop in vapor pressure (graph 4). This is the significant cause of the increase in inflammability which followed. Low vapor pressure (low absolute humidity) succeeds each storm in this region when the wind shifts from south and east to a westerly or northwesterly direction. Dry weather ensues until relieved by another storm. Dryness of the air is expressed both by the graph of a relative humidity (graph 1) and by the saturation deficit shown in graph 3. In the latter instance the width of the black zone indicates the capacity of the air for further absorption of water. The leaf fall, which began in the latter part of October, increased the hazard as shown on graph 4 by the prevalence of fires.

The rate of evaporation is conditioned upon three factors, temperature, humidity, and air motion. All three of these have a very definite relation to the move-

[1] The study of forest-fire weather in the Southern Appalachian region has been carried on by the Appalachian Forest Experiment Station at intervals since the fall of 1922. During this time two general phases of the subject have received attention—the relation of current weather conditions to forest-fire occurrence, and the rate of drying forest fuels under different conditions of weather. Two papers have been published on the first phase of this subject:

Forest Fire Weather in the Southern Appalachians. MONTHLY WEATHER REVIEW, April, 1923, 51: 182–185.

Forest Fires and Storm Movement. MONTHLY WEATHER REVIEW, May, 1924, 52: 257–259.

The present report presents in condensed form results of studies of the rate of drying of forest fuels made during the fall season of 1925 and the spring of 1926.

ment of storms, and none of them can be considered alone as the cause of forest dryness. Temperature has a direct effect upon the relative humidity, and the air motion also affects the humidity by the constant removal of the humid air from contact with the surface of the leaf litter. Of the three, temperature is the least important by itself, but the fact must not be disregarded that low relative humidity rarely occurs with low temperature during the fire season. These facts are cited because they bear on the analysis of the results obtained from the study of the rate of drying of litter.

If storms pass south of the Appalachian region, heavy precipitation usually occurs, lasting until the center has

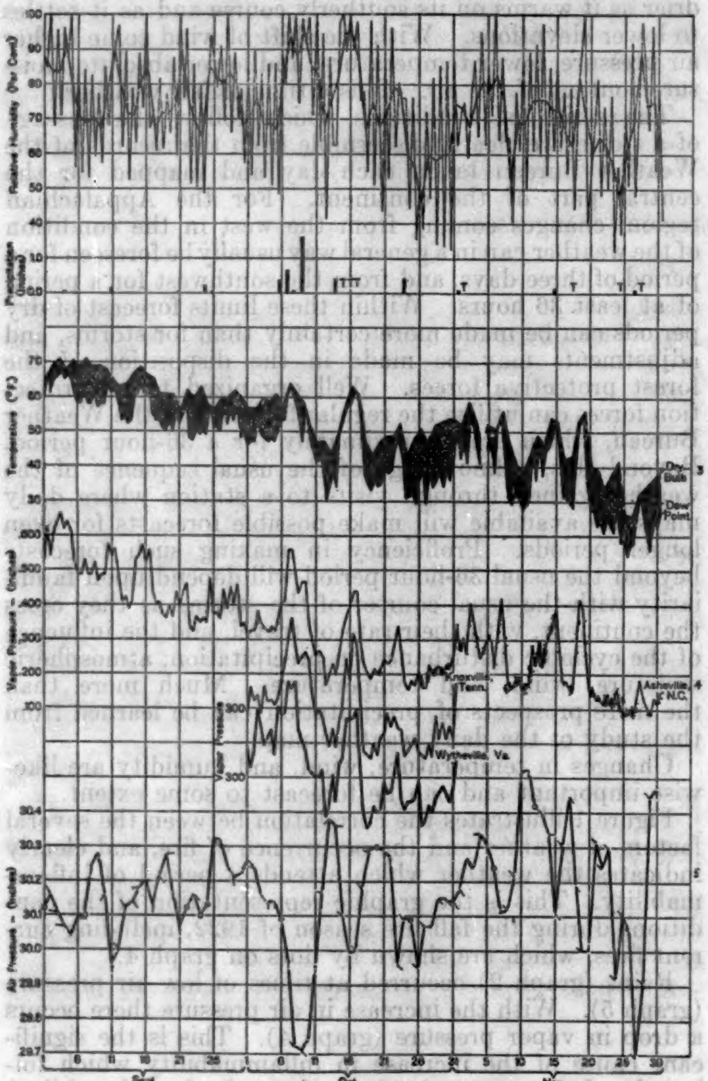

FIG. 1.—March of certain weather elements at the Appalachian Forest Experiment Station during September, October, and November, 1922

moved out into the North Atlantic. But if the storm passes up the Ohio Valley, though it usually brings rain to the Appalachian region, it may fail to do so. A storm passing over or adjacent to the Great Lakes region, without bringing precipitation to the Appalachians, increases the wind velocity and otherwise increases the fire hazard in the latter region both during and after its passage.

The foregoing discussion is intended to show that the periods of greatest inflammability in this region occur after the passage of a storm, and while the region is under the influence of the following anticyclone. Obviously the drying of the litter will lag behind the change to drier air. To determine the extent of this lag, tests of the drying rate were made during the fall fire season of 1925, and the spring season of 1926.

THE FALL FIRE SEASON, 1925

Meteorological records were kept from the 1st of October to the 24th of November on opposing north and south slopes on the Bent Creek experimental area of the Pisgah National Forest. In addition to these temperature, humidity, and rainfall records, samples of litter were tested for moisture content.

Weather conditions and leaf fall.—The season was generally unfavorable to fire. While the late summer and early fall were very dry, heavy rains just before the beginning of the leaf fall caused an apparent resumption of vegetative activity by the trees, so that they were in the main able to retain their leaves after the first heavy frost of October 10. The walnut, locust, and poplar were defoliated through the action of this early frost, but the bulk of the forest lost its leaves slowly. Even the rains of the first few days of November failed to bring down the leaf crop, although it had been subjected to repeated freezing during the last part of October. The rain of November 7 did cause the bulk of the leaves to fall, with the exception of those of the more resistant oaks, which, however, were practically all shed after the heavy rain of November 11. This extremely late leaf fall was quite as significant a factor in producing a safe fire season as was the prevalence of rain and high humidity. The late leaf fall alone would have delayed the fire season at least two weeks beyond the usual time.

Insolation.—The sun rises on the southerly exposures several hours before it begins to make a visible impression on the thawing of true north exposures. In fact, on some of the steeper north exposures, owing to the depression of the sun in the fall fire season, its rays must pass through a great extent of tree crowns at a very flat angle, and a few conifers in the forest will practically obstruct it for the entire day. This was observed to be the chief factor in creating a difference in the drying rate between the north and south exposures. On windy days the effect was less noticeable than on still mornings, when a heavy dew or frost was quickly dissipated by the sun on the south sides of the ridges but lingered until 10 a. m. or later on the north sides.

Character of litter and reaction to drying.—When the leaves first fell, they contained considerable sap and did not dry as readily as they did later. Resaturation of the litter under favorable conditions of moisture occurred very quickly, so that a relatively small amount of precipitation made the leaves noninflammable. Even a heavy dew caused the litter to become quite flexible, and the heavier rains during the test were little more effective in wetting the litter, except that the saturation of the soil increased the humidity of the air at the surface during the nights following the storm and caused reabsorption of water by the litter.

With the beginning of rain, hardwood litter absorbed water in excess of its dry weight in a comparatively few minutes, and gave up this water in the course of a few hours of dry weather down to a 40 per cent moisture content. The drying continued more slowly beyond this point, and the relatively fresh condition of the litter during the fall season checked the drying observed at about 8 per cent. Drying to below 10 per cent occurred only under very dry weather conditions.

All hardwood leaves showed a tendency to curl, creating air spaces in the litter. For this reason the wind was able to exert a more pronounced influence than it could had the litter been more compact. When the wind reached medium velocities, leaves drifted about the woods a great deal in spite of the heavy and frequent rains. Leaves on the south slope are deeper cut, both because of the site upon which they grow, and by reason of species; they also dry more rapidly than those of the north slope. For these reasons they curl up more and are blown about more than on a moister site.

An analysis of the weather during the period covered by this study (fig. 2) shows that the combined effects of late fall of leaves, frequent rains, and high humidities made this an unusually safe season. One of the most severe periods occurred after the rain of November 12, when 2.21 inches of rain fell during approximately 24 hours. The rain ceased about 4 p. m. on November 12. Relative humidity fell rapidly during the night, reaching

FIG. 2—RECORD OF RELATIVE HUMIDITY AND RAINFALL AT STATION ON SOUTH EXPOSURE—BENT CREEK—1925

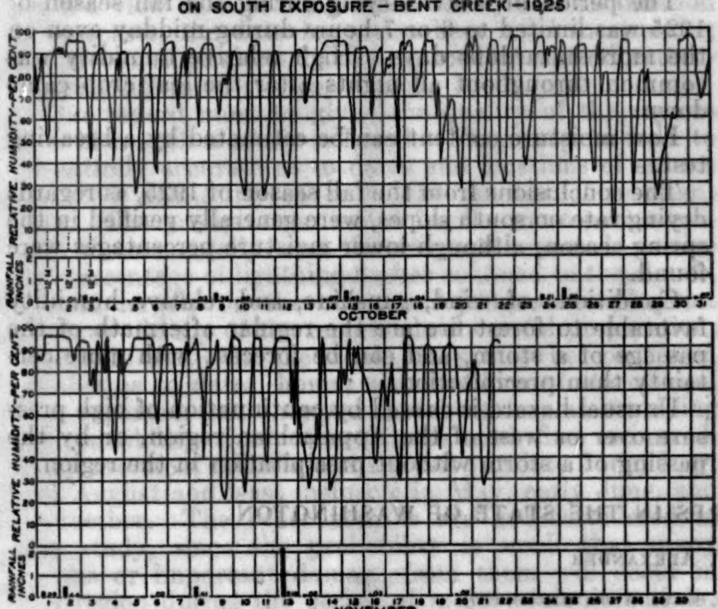

FIG. 2

26 per cent about noon on the 13th. A brisk wind blew during most of the day on the 13th. By 2 p. m. the litter on the south slope had become highly inflammable, as indicated by a burning test. Not only the new top litter but the older litter beneath was dry enough to burn. Seven samples of the top litter on the south exposure, taken between 2 p. m. and 3 p. m. on the 13th, showed an average moisture content of 9.4 per cent. The burning test was made upon litter of somewhat higher moisture content than this. Five litter samples taken at 11.30 a. m. on the following day (November 14) showed an average moisture content of the top litter on the south exposure of 16 per cent. This increase over the moisture percentage of the afternoon before was due entirely to the increase in humidity and the precipitation of dew on the night of the 13th. By midafternoon the average moisture content of the new litter was 10.8 per cent. Litter on the north exposure reached a moisture content of 18 per cent on the 14th and would have burned readily.

A second, less severe, period of drying occurred on November 17, 18, and 19. On the second day the average new litter on the south exposure dried out to about 10.8 per cent as in the previous case, though the top leaves which were in the sun reached a lower percentage than this. High night humidities and absence of wind made the drying slower than in the previous instance and reduced the night hazard to a very low level. These two periods were the driest that occurred between October 1 and November 24, after the fall of the leaf crop.

Physical determination of moisture content of litter.—In order to provide a field method for the determination of moisture content of the litter, about 50 determinations were made by weighing and correlated with series of breaking tests. While the heavier leaves, such as those of the post oak, crack or break with higher moisture content than the thinner leaves, such as white oak, the amount of this variation is not great. The following relations express the average results of these tests:

Leaves having 20 to 40 per cent moisture crack if creased, but do not break entirely.

With from 14 to 20 per cent moisture they crack if folded more than a right angle.

At an average of 14 per cent moisture they crack when bent at a right angle, but do not break freely, especially in the veins.

At an average of 10 per cent moisture they break entirely apart if bent at a right angle. Litter at 10 per cent moisture breaks up if crushed in the hand, but does not crumble into small pieces.

Freshly fallen leaves are tougher at any given moisture content than those which have been dried and saturated again.

EARLY SPRING CONDITIONS, 1926

Determinations of the moisture content of the leaf litter were made during three days (March 25–27) to get a more definite expression of the drying rate. Percentage of moisture was computed, as before, on the basis of the oven-dry weight. The leaf litter had been subjected to packing by snow and rain during the winter, so that very little of it was loose enough to blow about in winds of medium velocity. Repeated saturation, freezing in saturated condition, and drying had occurred also during the winter. The effect of compacting was to reduce the influence of the wind on the rate of drying in the spring, while at the same time the weathering of the litter probably caused it to dry more rapidly.

Samples of litter were collected during the day at intervals of 15 to 30 minutes, percentages of moisture were determined and these were used as the basis of an average curve of drying. Table 1 shows the results read from these curves.

TABLE 1.—*Percentages of moisture in litter* [1]

Hour	Mar. 24	Mar. 25	Mar. 26	Mar. 27	Mar. 28
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
8 a. m.		28.0	137.0	54.5	
9 a. m.		18.5	129.0	49.0	
10 a. m.		14.5	120.0	44.0	
11 a. m.		12.0	110.0	38.0	
12 m.		10.0	90.0	32.0	
1 p. m.		9.0	86.0	25.5	
2 p. m.		8.0	72.0	18.5	
3 p. m.		7.5	52.0	12.0	5.7
4 p. m.		7.0	25.0	5.0	
5 p. m.	6.0	13.0			
Number of samples	2	26	18	30	5

[1] Values read from an average curve.

Percentage of moisture in litter computed in all cases on the basis of oven-dry weight.

Two samples collected at 5.15 on March 24 showed an average of 6 per cent moisture, the result of two days' drying with light to medium winds, clear weather and relative humidity generally below 50 per cent. By 8 a. m. March 25 the wind had shifted to the south and vapor pressure was rising, but due to a considerable rise in temperature during the day the relative humidity ranged between 52 per cent and 38 per cent. A light rain started just before 5 p. m., continuing at intervals during the night. A fall of 0.24 inch of rain was recorded by the gauge at the place of the tests. This was enough to wet the top leaves, but not enough to wet the litter throughout.

The first determinations made on March 26 showed a moisture content of 137 per cent of the oven-dry weight. During the day, which was cloudy with a temperature below 50 degrees and a humidity above 50 per cent, the litter dried down to about 25 per cent. During the night of March 26, the relative humidity ranged from 70 per cent to 90 per cent, and the litter absorbed moisture up to 54.5 per cent at 8 a. m., March 27. This day was moderately dry with fluctuating light winds, and relative humidity remaining above 40 per cent. The litter dried out to about 5 per cent by 4 p. m., when the falling temperature caused the relative humidity to advance sharply. Freezing temperature developed during the night. Five determinations made on March 28 at 3 p. m. agreed within 2 per cent and averaged 5.7 per cent moisture content. At this time relative humidity was 19 per cent and vapor pressure 0.069 inch.

The period of these tests was not exceedingly dry except at its close. High night humidities, the absence of brisk winds, and comparatively low temperature were all unfavorable to rapid drying. Still on four days out of five the top litter had dried to 7 per cent or lower, and even on March 26 fire would have burned between the hours of 3 and 4 p. m. This series of tests tends to verify that of the fall of 1925, the conclusion being that one day of sunshine with even medium winds and humidity at or below 50 per cent creates a fire hazard. Temperature is chiefly important because of its influence upon relative humidity.

SUMMARY

After the fall of the new litter a fire hazard can be created through the agency of sun, wind, and low relative humidity on south exposures in a single day following a heavy precipitation.

On north exposures during the fall season, due to the small angle of insolation and shade cast even by hardwood crowns, no material hazard can be created in one day.

Wind is necessary for rapid drying, especially on north exposures.

Leaves absorb more than their dry weight of water and absorb moisture from moist air without the agency of rain, dew, or frost. The moisture content of litter is thus affected by night humidities.

The period of active drying during the fall season o 1925 was limited to 6 or 7 hours during midday even on the more hazardous days. High relative humidity was common throughout all nights after the leaf crop came down.

Low moisture content can be estimated by a breaking test.

The conclusions from the fall season of 1925, as regards drying rate on south slopes, were generally verified in the spring season, although lower moisture percentages were found.

Conditions of wind, sunshine, and relative humidity favorable to forest fire are the regular aftermath of the passage of a storm, and can be forecast with more certainty than precipitation.

Unusual hazard is caused by continuation of high pressure over or west of the Appalachian region, or by the passing of a storm without precipitation in the region.

LIGHTNING STORMS AND FOREST FIRES IN THE STATE OF WASHINGTON

By GEORGE W. ALEXANDER

[Fire-Weather Warning Service, Seattle, Wash., March 4, 1927]

The lightning storm, usually called the thunderstorm, might appear to be a somewhat unimportant climatic factor in the Pacific Northwest to one basing an opinion on published compilations of thunderstorm frequency. Isoceraunics based on reports from Weather Bureau stations for the 20-year period 1904–1923 (*1*) indicate an annual frequency of 5 storms or less for the coastal regions of Washington and 10 or less for the rest of the State, except the extreme southeastern corner. For the period of record at the different stations, varying from 35 to 45 years, the annual averages of number of storms reported are: For Seattle, 5; for Walla Walla, 7; and for Spokane, 8. The reported frequency for the entire Pacific coast is similar, except that an annual average of 15 storms is ascribed to eastern Oregon, to Idaho, and to western Montana.

On the other hand, reports of the number of lightning-caused fires on the national forests and on State and privately owned timberlands in the coast States show that such storms are of extreme importance. For the season of 1926 the grand total of lightning fires was 3,520, or 36 per cent of all the fires reported in California, Oregon, Washington, Idaho, western Montana, and British Columbia. Of these, 2,468 were on the national forests (51 per cent of all fires on the forests). For the 1926 season in the State of Washington there were 192 lightning fires on the national forests and 126 on private and State lands, being 48 and 11 per cent, respectively, of the total number of fires; and the damage caused, especially in eastern Washington, was even greater, in proportion to the total damage from fires, than the numerical percentage would indicate. For the season of 1925 the lightning fires on the national forests numbered 253 (54 per cent of the total) and on other lands 155 (13 per cent); the records for preceding years show similar numbers and percentages.

These figures indicate, especially to one studying the effect of weather on fire hazard, that, far from being negligible or incidental, lightning must be considered as of major importance, particularly in the mountainous regions in which is located most of the national forest area, and that fire-weather warnings which do not localize to the greatest possible extent the imminence of lightning storms fail in a large measure to achieve their purpose.

Realizing the need for complete data on the occurrence of lightning storms for purposes of both record and research, the Forest Service in 1924 furnished their mountain lookouts with forms on which to record the date, hours of beginning and ending, direction of movement, amount of accompanying precipitation, and other

pertinent data as to each storm passing within vision or hearing, with an accompanying report on all fires attributable to each storm. On many of the forests the number and location of lookouts makes it fairly certain that each storm, during the period the lookout stations were manned, has been reported. On other forests, where the general fire hazard is normally less and the number of lookouts is smaller and their season shorter, and on outside lands, where no such stations report, this is by no means the case, and it is fairly certain that unreported storms have occurred.

Reports from the national forests for 1924, 1925, and 1926 are now available, and, supplemented by those from cooperative observers and special fire-weather service observers of the Weather Bureau, and by reports of lightning-caused fires from the field personnel of the Washington Forest Fire Association, which covers western Washington outside the national forests, they have been made the basis of a survey of the frequency and geographical distribution of lightning over the State. With a view to improving the accuracy and localization of forecasts, the data have also been used in studying the meteorological conditions antecedent to and accompanying lightning storms.

Due regard must be given the quality of the reports on which such a study is based. They may be held to be entirely accurate as to dates and locations of storms reported, and fairly so as to the number of resultant fires. The precipitation is not for the most part measured instrumentally, and the amounts reported, as also the percentage of lightning flashes confined to the clouds, depend largely on the observer's judgment and point of view. Many of the reports show careful preparation; others do not. On the whole, they may be considered reliable as to dates, hours, and locations of storms and fires reported, but they can not be taken as excluding the possibility that other storms and fires occurred. They are most reliable and inclusive in late June, July, and August and least inclusive in May, early June, and September. The other months are not considered in this study, since the probability is small that many storms or important damage from them will occur in this region during the period of major cyclonic activity and comparatively low temperatures.

In 1924, from the beginning of reporting (various dates in July) to the closing of the lookout stations, lightning storms occurred on 21 days. There were 37 such days in 1925 and 29 in 1926. Reports of lightning fires indicate that there were probably storms on other days during these seasons, but the dates can not be fixed accurately. The numbers of storms reported vary with the location of the station and the length of the period reported on, from a minimum of 1 per season to a maximum of 14, with an average of about 8. Thus, based on the average number of storms reported per station rather than on the aggregate of days with storms, the frequency of storms for this region would be about that noted in the first paragraph.

The 87 known dates of storms noted above for the three seasons are the basis of this study. The location of each reported storm has been plotted on a map of the State, a separate map for each storm day. Pressure distribution, temperature, humidity, precipitation, and wind direction and velocity over the affected areas have been analyzed, to discover, if possible, the reasons for the known distribution of storms. For two reasons the synoptic charts for 8 p. m. (seventy-fifth meridian time) have been used in this study—first, because the abnormalities of pressure and temperature distribution most favorable to lightning storms are more notable on these than on the morning charts; second, fire-weather forecasts and warnings are distributed in this district in the evening, to aid in planning the next day's activities, and are based on conditions shown on the 8 p. m. charts.

Classification of storm types.—In attempting to group the 87 storms in relation to various types of pressure distribution (according to Humphreys' classification of thunderstorms (*2*)), four well-defined types of such distribution could be segregated.

Type I: Cyclonic, corresponding to Humphreys' "b" type (in the southeast or, less frequently, the southwest quadrant of a regularly formed LOW). Twenty-two of this type were noted. Contrary to the general rule, and for reasons to be stated later, in this region most of these occurred in the southwest quadrant of the LOW.

Type II: Anticyclonic, or trough storm, corresponding to Humphreys' type "d" (the region covered by a low-pressure trough between adjacent high-pressure areas). This type is most numerous, with 47 examples.

Type III: The border storm, corresponding to Humphreys' "e" type (along the boundary between warm and cold waves). This type was noted but once.

Type IV: This is a combination of Humphreys' classes "a" (regions of high temperature and widely extended nearly uniform pressure * * * local or "heat" storms) and "d" (defined under Type II), and is occasionally somewhat akin to "c" (barometric valley between the branches of a distorted or V-shaped isobar * * * the tornadic storm). It is marked by a somewhat variable distribution of pressure, but shows in all cases an area of relatively high pressure along the Pacific coast, or offshore, and an area of low pressure in the interior, wider than is the case under Type II, extending from the Cascade Mountains eastward, usually with a slight upward gradient toward the east, and marked by high temperature throughout. The area of high temperature and nearly uniform pressure may be extensive enough at times for the formation of heat thunderstorms, but the influence of the offshore HIGH, at least in Washington, is always to be seen during the life history of a Type IV storm. This type frequently develops from a storm of Type II. Among the 17 Type IV storms are the 2 which caused the greatest number of fires and the greatest damage in 1925 and 1926.

Data on the four types.—These are presented in the following tables:

TABLE 1.—*Annual distribution of storms*

Year	Type I	Type II	Type III	Type IV	Total
1924	0	14	0	7	21
1925	15	16	1	5	37
1926	7	17	0	5	29
Total	22	47	1	17	87

TABLE 2.—*Monthly distribution of storms*

Type	May	June	July	August	September	Total	Per cent of total
I	6	6	0	5	5	22	25
II	1	7	16	15	8	47	54
III	0	0	0	0	1	1	1
IV	0	0	7	6	4	17	20
Total	7	13	23	26	18	87	100
Per cent of total, by months	8	15	27	30	20	100	--------

TABLE 3.—*Geographical distribution of storms*

	Type I	Type II	Type III	Type IV	Total
Western Washington	7	11	1	8	27
Eastern Washington	16	41	0	13	70
Total [1]	23	52	1	21	[1] 97

[1] The apparent discrepancy between the totals noted in Tables 2 and 3 is due to the fact that certain storms extended over both sections; hence a duplication in noting distribution.

TABLE 4.—*Storms resulting in fires, 1925 [1] and 1926 [1]*

	Type I	Type II	Type III	Type IV	Total
In western Washington:					
All storms	4	7	1	2	14
Storms causing fires	2	5	1	1	9
Percentage of storms causing fires	50	71	100	50	65
In eastern Washington:					
All storms	18	26	0	8	52
Storms causing fires	1	13	0	3	17
Percentage of storms causing fires	6	50	0	38	33

[1] These years marked by more complete data on storms and fires.

TYPE CHARACTERISTICS

Type I (see fig. 1, pressure distribution at 8 p. m., August 31, 1925).—This, the cyclonic type, occurs most frequently in May, early June, late in August, and in September. (See Table 2.) During these months regularly formed LOWS, causing more or less general precipitation, rather frequently pass eastward over southern British Columbia or northern Washington. The lookout stations are not manned during the periods of greatest frequency (early and late in the season). Reports from the mountain districts during these periods would undoubtedly increase the number of recorded lightning storms attributable to this type of pressure distribution. Most of the lightning storms in western Washington accompany LOWS of this type which pass directly eastward from the North Pacific. Most of the LOWS affecting only eastern Washington are of the "Alberta" type, in which we find the lightning storms in the southwest quadrant, more commonly in August and September. When this type occurs there in normally a moderate temperature gradient between coast and inland stations, with relative humidity at or near the seasonal normal. Accompanying precipitation usually precludes any great danger from fires; in fact (see Table 4), but one fire in eastern Washington during the period of the survey has been chargeable to a storm of this type and but two of record in western Washington.

Type II (see fig. 2, pressure and temperature distribution at 8 p. m., July 10, 1926).—This, the "trough" or anticyclonic, is preeminently a summer or hot-weather type, and is responsible for 54 per cent of the storm days reported. Occurring most frequently in July and August, which are normally the periods of greatest fire hazard, with low humidity, light precipitation, and highly inflammable fire material, it is not strange that in 1925 and 1926 fires occurred with 70 per cent of the lightning storms of this type in western Washington and with 50 per cent of those in eastern Washington. The favorable pressure and temperature distributions are as follows: High pressure and comparatively low temperature along the coast and over the western section, with north-south isobars and isotherms, roughly parallel, and with low pressure and high temperature in the barometric valley, with a further gradient toward the east similar to but less steep than that toward the west. This situation presents, in effect, a "cold front" on the west and to a less degree on the east. Thus there is an overrunning of cool, moist air currents in connection with strong vertical convection and up-valley and up-mountain winds in the interior. This is a condition most favorable for extreme turbulence along the contacts of the conflicting air currents, and for the establishment of an adiabatic or superadiabatic gradient at or near the summits of the mountain ranges, from the Cascades eastward to include the Okanogan Highlands. Lightning storms result, scattered at times over large areas. The course of travel of each storm, its intensity, and the effectiveness of accompanying precipitation depend in each case on conditions at and close to their point of origin and on the immediately ensuing changes in the distribution of pressure and temperature.

Because the north-south isobars of lowest pressure in the trough seem frequently to be closed on the north and south (usually from lack of data that would call for their extension on the chart) this type frequently bears a surface resemblance to Type I. It can usually be distinguished, however, as being due to local conditions rather than to the eastward passage of a regularly formed LOW.

Type III. The border storm, or "cold-front" type.—This appears as a trough of low pressure, with its main axis in a general east-west direction, not north-south as in Type II. But one example has been noted during the three seasons of the survey—the storm of September 28, 1925. In this case the pressure gradients were not very steep, nor the temperature gradients remarkably so. Lightning was general in Washington west of the Cascades, and started many fires. Precipitation, while generally only of the order of 0.25 inch, was sufficient, with the high humidity, to prevent any great damage by the fires. The trough was the eastern extension of a secondary LOW of moderate intensity, moving southeastward in the path of a predecessor then central over Utah. The fact that the summer path of LOWS is normally somewhat farther north would seem to indicate that this type of storm should be comparatively infrequent and of little consequence except at the beginning and near the end of the fire season, when other conditions cause the fire hazard to be relatively low.

Type IV (see fig. 3, pressure and temperature distribution at 8 p. m., July 11, 1926).—This is a combination type, as has been stated. While it prevails there are frequently lightning storms that might be classified under the "heat" or "local" types in the region of high temperature and fairly even pressure farther east over Idaho and western Montana. In fact, such was the case on July 12, 1926, with widely spread storms and damaging fires in those States and in southeastern British Columbia. In Washington, however, the coastal high-pressure ridge is the normal seasonal condition. The onshore westerly winds induced thereby, adiabatically cooled in passing over the Cascades, may be regarded as the vehicles for the moisture necessary for the production of lightning storms on the eastern slopes of the mountains and over the hot, dry interior plateau.

DISTRIBUTION OF STORMS

While the various pressure types are generally quite obvious, two very important problems are to be considered in forecasting lightning storms for the forestry interests: First, the area to be affected must be delimited; second, the probability of effective precipitation must be indicated, and whether it will be fairly general over the area, or entirely local, confined to the space immediately under the storm clouds, and hence varying greatly in amount from place to place. A study of the exemplars

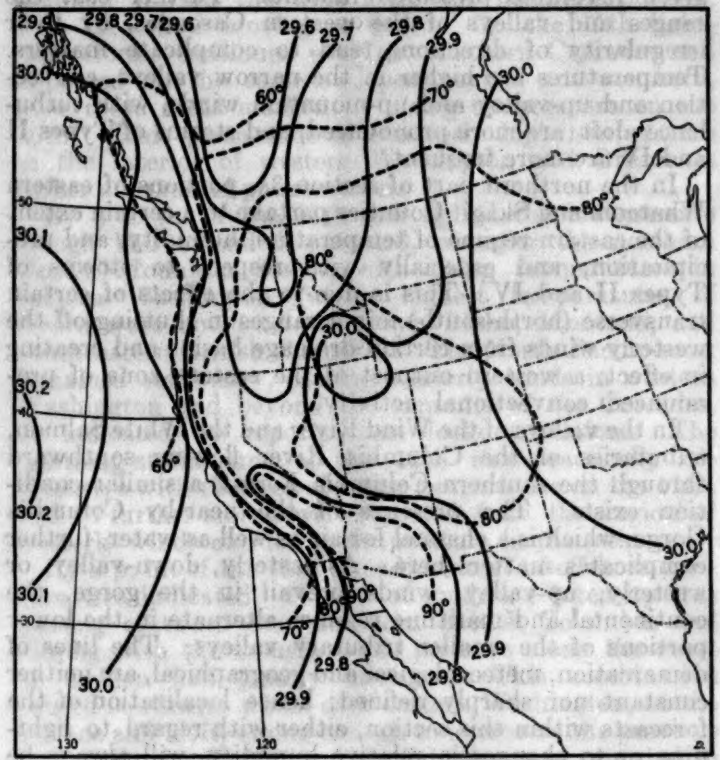

FIG. 1.—Distribution of pressure and temperature over the western United States at 8 p. m., August 31, 1925, resulting in lightning storms of Type I (cyclonic)

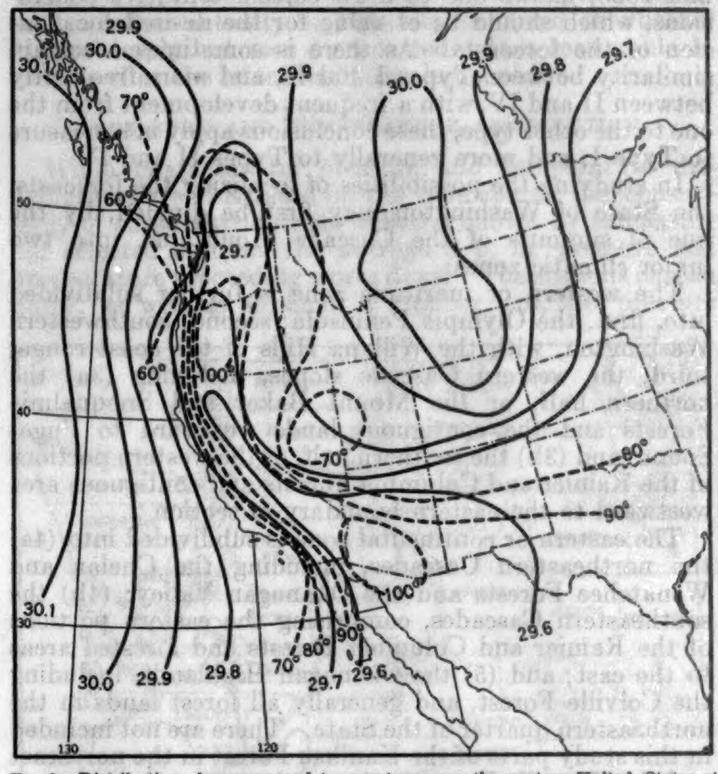

FIG. 2.—Distribution of pressure and temperature over the western United States at 8 p. m., July 10, 1926, resulting in lightning storms of Type II (anticyclonic)

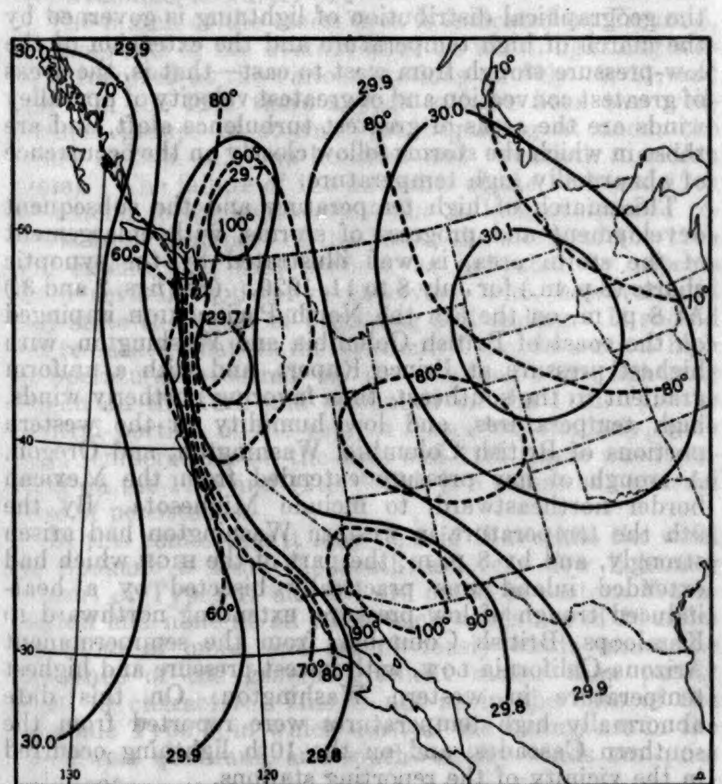

FIG. 3.—Distribution of pressure and temperature over the western United States at 8 p. m., July 11, 1926, resulting in lightning storms of Type IV (combination)

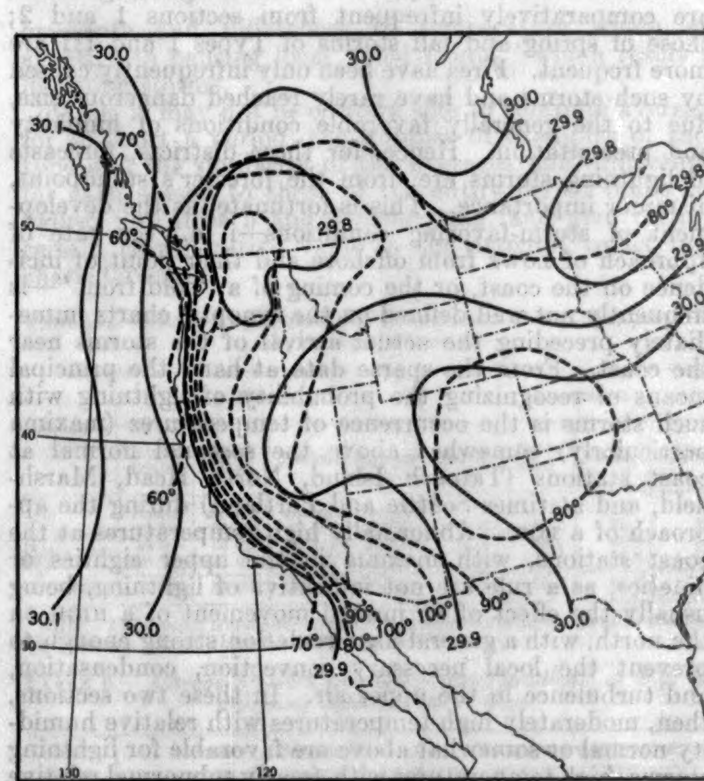

FIG. 4.—Distribution of pressure and temperature over the western United States at 8 p. m., July 12, 1926, resulting in lightning storms of Type IV

of Types II and IV, especially for the seasons of 1925 and 1926, allows one to draw certain tentative conclusions, which should be of value for the desired localization of the forecasts. As there is sometimes a certain similarity between Types I and II, and more frequently between II and IV, with a frequent development from the one to the other type, these conclusions apply in a measure to Type I, and more generally to Types II and IV.

In studying the possibilities of localizing the forecasts, the State of Washington may first be divided, by the line of summits of the Cascade Mountains, into two major climatic zones:

The western or maritime zone is further subdivided into, first, the Olympic Peninsula; second, southwestern Washington, with the Willapa Hills of the coast range; third, the western Cascade slopes, including (3a) the northern half, or the Mount Baker and Snoqualmie Forests and the contiguous lands westward to Puget Sound, and (3b) the southern half, or the western portions of the Rainier and Columbia Forests and contiguous area westward to the eastern boundary of section 2.

The eastern or continental zone is subdivided into (4a) the northeastern Cascades, including the Chelan and Wenatchee Forests and the Okanogan Valley; (4b) the southeastern Cascades, comprising the eastern portions of the Rainier and Columbia Forests and forested areas to the east; and (5) the Okanogan Highlands, including the Colville Forest, and generally all forest lands in the northeastern quarter of the State. There are not included in this study parts of the Kaniksu Forest in the northeast and the Umatilla Forest in the southeast, as these forests lie mainly in Idaho and Oregon, respectively; nor the unforested plateau of southeastern Washington.

Sections 1 and 2.—Reports of summer lightning storms are comparatively infrequent from sections 1 and 2; those of spring and fall storms of Types I and III are more frequent. Fires have been only infrequently caused by such storms and have rarely reached dangerous size, due to the generally favorable conditions of humidity and precipitation. Hence, for these districts, forecasts of lightning storms are, from the forester's standpoint, of minor importance. This is fortunate, as the development of storm-favoring conditions—i. e., the rate of approach of LOWS from offshore and their point of incidence on the coast, or the coming of a "cold front"—is frequently not well defined on the synoptic charts immediately preceding the actual arrival of the storms near the coast. From the sparse data at hand the principal means of recognizing the probability of lightning with such storms is the occurrence of temperatures (maxima particularly) somewhat above the seasonal normal at coast stations (Tatoosh Island, North Head, Marshfield, and at times Seattle and Portland) during the approach of a LOW. Abnormally high temperatures at the coast stations, with maxima in the upper eighties or nineties, as a rule are not indicative of lightning, being usually the effect of an inward movement of a HIGH on the north, with a general air circulation strong enough to prevent the local necessary convection, condensation, and turbulence in the upper air. In these two sections, then, moderately high temperatures with relative humidity normal or somewhat above are favorable for lightning storms; high temperatures with greatly subnormal relative humidity are unfavorable.

Sections 3a and 3b.—The western portion of these subdivisions—that is, the eastern Puget Sound Valley and the valleys of the upper Chehalis and lower Cowlitz Rivers—presents conditions comparable to those of sections 1 and 2. Type I storms are most frequent, and temperature and humidity are the best indices of storm probability, given favorable pressure gradients. Farther east the ranges and valleys of the western Cascades, by their irregularity of direction, tend to complicate matters. Temperatures are higher in the narrow valleys, convection and up-valley and up-mountain winds, with turbulence aloft, are more pronounced, and storms of Types II and IV are more frequent.

In the northern part of section 3a, portions of eastern Whatcom and Skagit Counties partake to a certain extent of the eastern régime of temperature, humidity, and precipitation, and especially with respect to storms of Types II and IV. This is due to the effects of certain transverse (north-south) minor ranges in shutting off the westerly winds from certain drainage basins and creating in effect, a western outpost of the eastern zone of pronounced convectional activity.

In the valleys of the Wind River and the White Salmon, tributaries of the Columbia River flowing southward through the southern Columbia Forest, a similar condition exists. The presence of the near-by Columbia Gorge, which is a channel for air as well as water, further complicates matters here. As easterly, down-valley, or westerly, up-valley, winds prevail in the gorge, the continental and maritime régimes alternate in the lower portions of the smaller tributary valleys. The lines of demarcation, meteorological and geographical, are neither constant nor sharply defined; hence localization of the forecasts within this section, either with regard to lightning or to changes in relative humidity, will always be rather difficult.

An examination of the synoptic charts just prior to storms in this southern Cascade region discloses one salient fact. Given similar types of pressure distribution the geographical distribution of lightning is governed by the march of high temperature and the extension of the low-pressure trough from west to east—that is, the areas of greatest convection and of greatest velocity of up-valley winds are the areas of greatest turbulence aloft, and are those in which the storms follow closely on the occurrence of abnormally high temperature.

This march of high temperature and the subsequent development and progress of storms, with enlargement of the storm area, is well illustrated by the synoptic charts (8 p. m.) for July 8 to 11, 1926. (See figs. 2 and 3.) At 8 p. m. on the 8th the North Pacific HIGH impinged on the coast of British Columbia and Washington, with highest pressure at Prince Rupert, and with a uniform gradient to the southeast, thus favoring northerly winds, high temperatures, and low humidity in the western portions of British Columbia, Washington, and Oregon. A trough of low pressure extended from the Mexican border northeastward, to include Minnesota. By the 9th the temperature in western Washington had arisen strongly, and by 8 p. m. the part of the HIGH which had extended inland was practically bisected by a heat-induced trough of low pressure, extending northward to Kamloops, British Columbia, from the semipermanent Arizona-California LOW, with lowest pressure and highest temperature in western Washington. On this date abnormally high temperatures were reported from the southern Cascades, and on the 10th lightning occurred in the vicinity of the reporting stations.

Conditions remained similar on the 10th (see fig. 2)—that is, high pressure along the coast, and with the trough central at Kamloops and Portland. The temperature continued to rise in the interior of the west portion of the two States (the absolute highest of record being reported from Portland and Roseburg on this date). There re-

mained an area of moderately high pressure, with a lesser gradient toward the west, over the northern plateau, with its center moving eastward. On the 11th lightning storms continued over the southern Cascades and appeared on the eastern slopes, central and southern, over those areas marked by rising temperature on the 10th. (This persistence of extremely high temperature in the interior of western Washington and Oregon is rather an unusual phenomenon.)

By 8 p. m. of the 11th (see fig. 3) the low-pressure trough had extended eastward, covering the northern Rocky Mountain States, with rising temperatures in eastern Washington (where highest temperatures of record were noted on this day), Idaho, Montana, and southeastern British Columbia. The North Pacific HIGH remained stationary, causing westerly winds in western Washington and beyond the summits of the Cascades, as indicated by reports from lookout stations. The lightning-storm area of the 12th was practically coextensive with the area of rising temperature on the 11th, and no further storms were reported from the region of westerly winds and lower temperature in the west.

By 8 p. m. of the 12th a readjustment of offshore pressure was indicated. A LOW of moderate intensity was passing eastward over southern British Columbia and joining with the trough, while pressure along the coast of Oregon had greatly increased. This combination caused southwest winds over eastern Washington, at the surface and aloft, strong enough to overcome the previous convectional activity, and no lightning was reported in Washington after 11 p. m. on that date. It is believed that the storms continued during the early morning of the 13th in Idaho and British Columbia; exact data are not available, however.

The march of the storm area is indicated on Figure 5, by isobronts of the average hour on which lightning was first reported at the various stations on July 10, 11, and 12. On the 12th there appear to have been two well-defined groups of storms, one beginning at noon, the other at 2 p. m. (one hundred and twentieth meridian time). The failure of the isobronts of the 11th and 12th to extend to the southeast is due to lack of detailed reports from that part of the State; the storm of the 12th did extend over that section, as indicated by reports from several cooperative observers, who, however, did not state the hours of beginning and ending. It should be remarked that in the southern Cascade section high temperatures occurred on the 9th and 10th; lightning began on the 10th and continued on the 11th. In the central portion of the eastern Cascades, similarly, with high temperatures on the 10th and 11th, there was lightning on the 11th and 12th. This is a somewhat unusual case of persistence.

In this connection it may be said that while the wind at Spokane is from the southwest very few lightning storms of Types II and IV are noted in eastern Washington and none at all when such winds are of 10 miles per hour or more, and are obviously winds under the influence of the general gradient rather than purely local in character. This is not so in the case of the cyclonic Type I, in which most of the storms are in the southwest quadrant, and southwesterly winds are quite frequent.

While the typical storms just discussed are distinctive and the correlation between cause and effect quite obvious, the situations are usually rather more complex; hence extensive generalization seems unsafe. A study of the synoptic charts for the three summers shows, in fact, frequent recurrences of what appear to be very good lightning-storm types, following which no lightning has been reported. In such cases, however, it is uncertain whether actually no lightning occurred or whether it was simply not seen or reported. It is reasonable to believe that the latter has often happened.

PRESSURE AND TEMPERATURE DISTRIBUTION

While characteristic pressure and temperature distributions are illustrated on the type charts, the consistency of these distributions is better shown by tabulating for selected stations the average 8 p. m. pressure and temperature preceding storm days. The stations chosen show, as well as so small a number can, the pressure

FIG. 5.—Isobronts: Average hour of beginning of lightning in series of storms of July 10, 11, and 12, 1926

gradients and differences in temperature which are effective in causing local "cold fronts," which result in lightning storms.

While it may not be entirely safe to compute averages for so short a period, the number of examples of each type and the similarity of the averages and differences for each season to those of the entire period make the figures in Tables 5 and 6 interesting, and give them a certain corroborative value in the attempt to fix type characteristics.

TABLE 5.—*Average pressure and temperature at 8 p. m., preceding lightning-storm days*

Storm type	Pressure				Temperature			
	Tatoosh Island	North Head	Yakima	Spokane	Seattle	Portland	Yakima	Spokane
	Inches	*Inches*	*Inches*	*Inches*	°	°	°	°
I	29.924	29.967	29.853	29.822	64.6	67.6	71.7	72.4
II	30.006	30.022	29.811	29.854	71.8	78.1	87.6	84.8
IV	30.025	30.039	29.833	29.857	71.3	76.8	83.6	82.5
Average	30.003	30.021	29.825	29.848	70.1	75.5	83.2	81.8

NOTE.—The average is computed from the total number of dates, not as an average of type averages. Type III is omitted from the tabulations.

TABLE 6.—*Average pressure and temperature gradients at 8 p. m., preceding lightning-storm days*

Storm type	Pressure differences				Temperature differences			
	North Head-Tatoosh	Yakima-Tatoosh	Spokane-Tatoosh	Spokane-Yakima	Portland-Seattle	Yakima-Seattle	Spokane-Seattle	Spokane-Yakima
	Inch	*Inch*	*Inch*	*Inch*	°	°	°	°
I	0.043	−0.071	−0.102	−0.031	3.0	7.1	7.8	0.7
II	.016	−.195	−.152	.043	6.3	15.8	13.0	−2.8
IV	.014	−.192	−.168	.024	5.5	12.5	11.2	−1.3
Average	.018	−.178	−.155	.023	5.4	13.1	11.7	−1.4

LIGHTNING STORMS AND FIRES

While the occurrence of lightning storms and the possibilities of accurately forecasting them are of prime interest to the meteorologist, to the forester such storms are interesting mainly because they cause fires. Since not every storm starts a fire, even though widespread and marked by intense electrical display, the number of lightning fires and the extent of the damage must be affected by weather conditions which precede and follow the actual lightning flashes.

In a very exhaustive analysis of the lightning reports from the lookout stations in Forest District No. 1 (northern Rocky Mountain region) for the years 1924 and 1925, Mr. H. T. Gisborne (*3*) has suggested that the difference in the number of lightning fires during these years may be explained by the difference in average duration of rainfall before and after the first and last flashes of each storm were observed, and by a small difference in the averages of the reported percentage of flashes confined to the clouds.

The lightning reports for the three seasons in Washington are made on the same form, contain the same classes of information, and are presumably about as accurate as those in District No. 1. A scrutiny of the percentage of flashes reported as having been confined to the clouds and of the total number of flashes in each storm (the latter not always stated) indicates that such a comparison of percentages as between "safe" (nonfire-causing) and "dangerous" (fire-causing) storms can not at present be given much weight as determinants of the safety factor. This conclusion is based on the following items:

(*a*) Probability of error in determining the number and striking point of flashes.

(*b*) Probability of error in computing percentages. This is because the number of cloud-to-cloud flashes and of cloud-to-earth flashes are not specified, nor even the total number of flashes in many cases. One observer reported for a certain storm a total of one flash, with 75 per cent of flashes from cloud to cloud.

The percentages are interesting, and they would, if the data were unimpeachable, be important.

There is a similar lack of authority in the reports as to the duration of precipitation before and after the flashes. The lookouts report this in minutes (duration of period between flashes having to be interpolated) and the amounts of precipitation, as light, moderate, or heavy, with occasional qualifying adjectives. In but few cases are instrumental measurements given. During certain storms the amounts reported vary from none, through light, to extra heavy (for the same storm and within a circumscribed area), which is quite natural and to be expected. At times those stations reporting heavy precipitation report numerous fires, while those reporting no rain or little, report few or no fires; occasionally the reverse is true. This, due to the purely local character of most of the summer storms of Types II and IV, is also natural and to be expected. Also, one must consider the fact that bolts from local lightning storms not infrequently strike at points somewhat distant from the region immediately beneath the storm cloud (*4*), which would receive the greatest amount of precipitation. Hence the quantity or duration of precipitation reported by individual observers for any fixed points is not a valid index to use in classifying the storms as "safe" or "dangerous."

In addition to the precipitation reported by the lookouts I have considered the precipitation reported by regular cooperative observers. To correlate numerically the precipitation amounts with the number of fires resulting from any given storm has not been practicable, but there has been noted a fairly close relation between the number of fires and the extensiveness of the rainfall. In cases where precipitation has occurred at only a few very scattered stations, even with amounts ranging from a trace to 0.90 or 1 inch (the lookouts reporting from "very light" to "extra heavy"), numerous fires have been reported. Types II and IV are characterized by this variable, localized precipitation, and for eastern Washington are preeminently the dangerous storms. Again, with precipitation rather light, 0.01 to 0.30 inch in varying amounts, but *general*, thereby increasing the probability of effective amounts precisely at the location of the lightning strikes, few fires, and generally none, have been reported. Such as are reported are usually easily extinguished, being for the most part class A fires (one-fourth acre or less). This general spread of precipitation is characteristic of the cyclonic Type I and partly explains its comparative innocuousness.

In western Washington reports of storms of Types II and IV are fewer but the percentage of dangerous storms of these classes is greater than in the eastern section. This is partly because over a rather large area the chief source of information about the occurrence of storms has been the reports of fires caused by them, and probably partly because the more abundant fire material is at its seasonal peak of inflammability during the lightning season. Precipitation in this section during the known dangerous storms has been light and scattered, except in the one notable example of Type III.

Relative humidity and temperature before and just after storms probably affect their fire-causing character more than do attendant conditions. An examination of conditions prior to and subsequent to the storms that have resulted in the most widely destructive fires discloses two significant features—high temperature and low relative humidity prevail before and after the storms, and changes in these elements during the storm are of but brief duration. The effect is threefold: Forest materials have become highly inflammable just prior to the storm, the amount of effective precipitation is lessened by partial evaporation of the rain as it falls (complete evaporation before reaching the ground has been frequently noted in arid regions under similar circumstances), and rain that does reach the earth is evaporated very rapidly, the régime of high hazard being quickly reestablished.

Pressure distribution and temperature at 8 p. m. just preceding dangerous storms are shown in Tables 7 and 8 and the relative humidity for the same observation in Table 9 following:

TABLE 7.—*Average pressure and temperature distribution at 8 p. m., preceding "dangerous storms"*

	Pressure				Temperature			
	Tatoosh Island	North Head	Yakima	Spokane	Seattle	Portland	Yakima	Spokane
Western Washington, dangerous storms	29.903	29.893	29.786	29.820	77.2	83.3	88.0	84.7
Eastern Washington, dangerous storms	29.981	30.019	29.773	29.803	75.0	80.3	92.6	90.3
Eastern and western Washington, all storms	30.003	30.021	29.825	29.848	70.1	75.5	83.2	81.8

TABLE 8.—*Average pressure and temperature gradients at 8 p. m., preceding "dangerous storms"*

	Pressure difference				Temperature difference			
	North Head-Tatoosh	Yakima-Tatoosh	Spokane-Tatoosh	Spokane-Yakima	Portland-Seattle	Yakima-Seattle	Spokane-Seattle	Spokane-Yakima
Western Washington, dangerous storms	−0.010	−0.117	−0.083	0.034	6.1	10.8	7.5	−3.3
Eastern Washington, dangerous storms	.038	−.208	−.178	.030	5.3	17.6	15.6	−2.3
Eastern and western Washington, all storms	.018	−.178	−.155	.023	5.4	13.1	11.7	−1.4

TABLE 9.—*Average per cent of relative humidity at 8 p. m., preceding "dangerous storms"*

	Seattle	Portland	Wind River Experiment Station	Darrington	Spokane	Republic	Leavenworth
Western Washington, dangerous storms	44.6	44.0	42.0	45.0			
Eastern Washington, dangerous storms	46.9	46.1			19.2	23.8	23.5
Eastern and western Washington, all storms	52.0	48.8	44.0	50.0	25.1	27.6	29.3

As pointed out previously, pressure and temperature distribution govern the location of the storms. From the three tables above it will be seen that the degree of accentuation of a given type of pressure and temperature seems to govern the degree of danger from the individual storm. Except that lightning fires are often harder to suppress than others, because they often occur in inaccessible locations, they are, once started, no different from those originating from any other source. They react in like manner to changes in the "fire-weather" conditions. During the period 1916–1926, for which specific figures for the national forests are available, every period marked by great damage from lightning fires in the Washington forests (the acreage burned over being the index of damage) has been preceded by generally subnormal precipitation and relative humidity, and the fires were neither controlled nor suppressed until these subnormal conditions were relieved.

Forestry interests have suggested that forecasts of lightning storms include some indication as to the expected "safe" or "dangerous" character of the storm. Having in mind the fact that the degree of danger to be expected varies inversely with the amount and extensiveness of the accompanying precipitation and with changes in the fire hazard, we may ordinarily consider that storms of Type I (usually occurring during periods of nearly normal humidity and attended by general rainfall) are "safe"—that is, few, if any, fires are to be expected. But the very nature of Types II and IV, typical summer storms, with scattered, light precipitation and subnormal humidity, would usually preclude the possibility of such a predesignation, except under extraordinary circumstances.

It may not be feasible to forecast "safe" storms in July and August, but, on the other hand, it may at times be entirely proper to include in the forecast, when a storm is seen to impend during a period of generally high fire hazard but without probability of ameliorating the conditions, a statement that general conditions favor the establishment of fires. While general verification of such a forecast might not be expected over any large area, the information might be of value in regulating the activities of suppressive forces in zones known to be particularly subject to storms and to lightning fires.

The ignition of forest material by lightning would seem to be somewhat fortuitous, depending on whether the strikes are on inflammable material, as growing trees, snags (tall dead trees or stumps), duff, or moss, or on the bare mineral earth or grassy meadows. There is dearth of authenic information as to the material in which most fires start. Strikes are frequent on green trees and tall snags, as may be seen from their splintered condition. Whether fires in such cases are caused by blazing splinters, ignited moss, or in the duff ignited during the grounding of the bolt is difficult to determine, as in most cases the evidence is consumed before examination is possible. There seem to be certain well-defined storm paths, and in these paths certain areas are marked by many fires. While topography would influence the conditions that cause storms, and hence the storm paths, the reasons for differing susceptibility to fires will have to be determined by investigation in each district.

CONCLUSIONS

1. Lightning storms are of outstanding importance among the meteorological phenomena affecting the fire hazard in Washington, and in the Pacific Coast States in general. Localization of forecasts of such storms is highly desirable.

2. Such storms in Washington, with reference to the pressure distribution causing them, are classified under four types—I, the cyclonic; II, the trough, or anticyclonic; III, the border storm; IV, a combination of the trough and the local or heat storm.

3. Storms of Type I are least dangerous, from the standpoint of resultant fires and damage, while those of Type III are infrequent. Fires are very probable after storms of Types II and IV. High pressure along the coast and high temperatures in the interior, with pronounced gradients, are the dominating features attending the dangerous types.

4. The local occurrence of lightning storms is governed by orographic and climatic conditions, the storms being most frequent in zones of highest summer temperature, with marked convectional activity and up-mountain winds. Given suitable pressure distribution, individual storms follow the march of high temperature from west to east at an interval of 12 to 36 hours after the temperature maxima. This should allow us to localize the forecasts.

5. The occurrence of fires after storms seems to be limited by the degree of distribution and the amount of accompanying precipitation, rather than by its purely local intensity. The extent of damage from such fires is governed by the seasonal degree of inflammability of the fire material and by the occurrence of fire weather before and after the fires are established.

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MARCH TEMPERATURE AND THE FOLLOWING SEASON'S PRECIPITATION IN COASTAL SOUTHERN CALIFORNIA

By GEORGE M. FRENCH

[Weather Bureau Office, Los Angeles, Calif.]

This study of the Los Angeles and San Diego temperature and precipitation records sought to ascertain if there was any relation between the temperature of certain months during the early part of, or previous to, our season

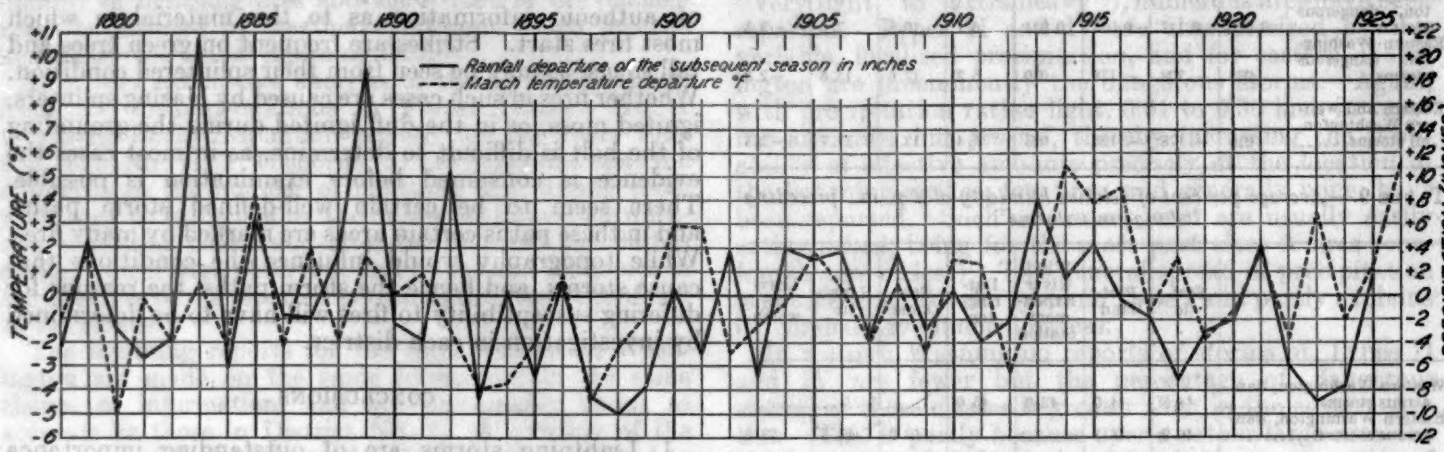


FIG. 1.—March temperature departure in °F., and the rainfall departure of the subsequent rainy season in inches, Los Angeles, Calif.

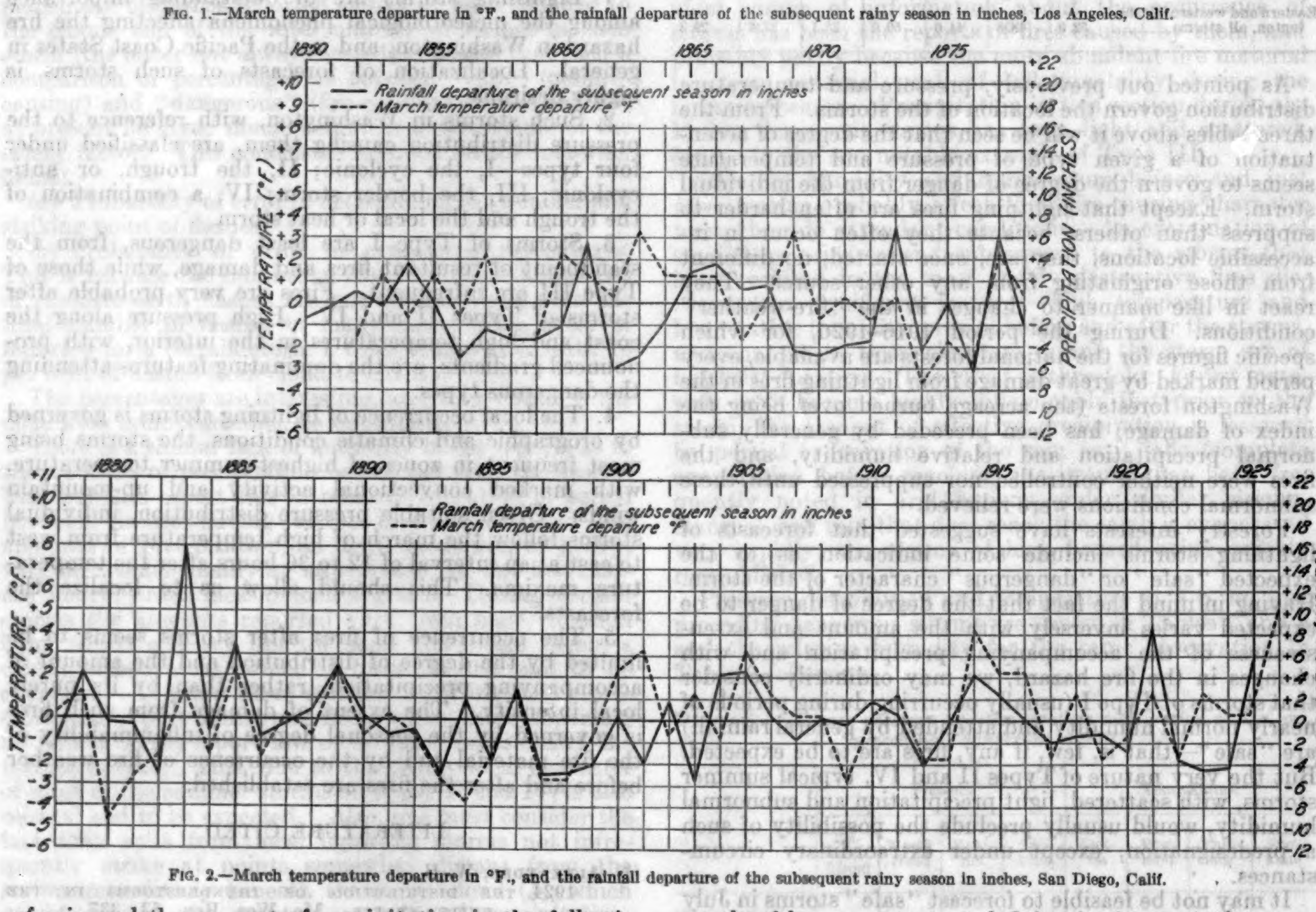


FIG. 2.—March temperature departure in °F., and the rainfall departure of the subsequent rainy season in inches, San Diego, Calif.

of rain and the amount of precipitation in the following rainy season.

A graph was prepared with a curve showing the normal temperature by months for the calendar year, a second curve showing the average monthly temperatures for all years of the Los Angeles record with precipitation above normal, and a third for all years with precipitation below normal. Noteworthy departures were shown in this manner for the months of January, March, August, September, and December. In checking for frequency, however, I found that all save March seemed to be a result of large excesses or deficiencies in particular years instead of being a result of frequent occurrences.

This information eliminated all monthly temperatures except those of March as indicators of the amount of the following seasonal precipitation. Hence the graph in Figure 1 was made showing for Los Angeles how the seasonal precipitation and the preceding mean March

temperatures have varied from their respective normals. A similar chart covering the entire period of San Diego records was prepared, this being the only other regular Weather Bureau office in the coastal region of southern California.

Figure 1 shows that the precipitation for Los Angeles has been above normal when the preceding March temperature was above, and below when the March temperature was below, 74 per cent of the time. Figure 2 shows the same conditions 64 per cent of the time for San Diego with a record 27 years longer than that of Los Angeles.

This would tend to indicate that if the March temperature is above normal in the coastal region of southern California the chances would be considerably in favor of precipitation being above normal for the following season, and vice versa.

The temperature of March, 1926, equaled the highest mean for the month of March at the Los Angeles station and exceeded the highest mean for March at the San Diego station. At the close of March, 1927, both these stations had a total rainfall well above the normal for the entire season.

FORMULAE FOR THE VAPOUR PRESSURE OF ICE AND OF WATER BELOW 0 °C.

By F. J. W. WHIPPLE

[Kew Observatory, Richmond, Surrey, England, March 21, 1927]

In the MONTHLY WEATHER REVIEW, October, 1924 (pp. 488–490), Doctor Washburn published a valuable discussion of the vapour pressure of ice and of water below the freezing point. The formulae which he obtained from theoretical considerations are in beautiful agreement with observational data. In deriving his formulae, Doctor Washburn introduced two arbitrary constants, C and D, and evaluated these by reference to the experimental results. It appears, however, that simpler formulae can be written down which do not involve these arbitrary constants and which lead to the same numerical values. The agreement is really a demonstration that, over the range considered, the variation of specific heat with temperature can be ignored. The starting point is the Clausius-Clapeyron equation,

$$\frac{dp}{dT}=\frac{L}{(v-V)\,T},$$

in which p is the vapour pressure,
T is absolute temperature,
L is the latent heat of evaporation,
and $v-V$ is the change of volume on evaporation.

As Doctor Washburn mentions, V, the specific volume of water is negligible in comparison with v the specific volume of vapour.

We assume that the latent heat of evaporation at the centigrade temperature t is

$$L_v-(S_w-S_v)t$$

where L_v is the latent heat of evaporation at 0° C. and Sw and Sv are the specific heats of water and vapour at that temperature, and find (with Hertz) that the formula for vapour pressure over water is

$$\log_{10}\frac{p}{p_0}=\frac{J}{R}\left[\left(\frac{L_v}{T_0}+S_w-S_v\right)\log_{10}e\,\frac{t}{t+T_0}-(S_w-S_v)\log_{10}\frac{T_0+t}{T_0}\right]$$

Here p is the required vapour pressure,
p_0 is the vapour pressure at 0° C.,
J is the mechanical equivalent of heat,
R is the gas constant,
$t+T_0$ is the absolute temperature.

The formula for vapour pressure over ice is of the same type.

Using the numerical values,

$$L_v=597,\ L_F=79.8,\ T_0=273.1$$
$$S_w=1.009,\ S_1,=.5057,\ S_v=.457$$
$$\text{and } R/J=.1103\ \frac{\text{Cal}}{\text{deg. gm.}},$$

we get the following formulae:

(1) For vapour pressure over water

$$\log_{10}\frac{P}{P_0}=10.78\,\frac{t}{273.1+t}-5.01\,\log_{10}\frac{t+273.1}{273.1}$$

(2) For vapour pressure over ice

$$\log_{10}\frac{P}{P_0}=9.95\,\frac{t}{273.1+t}-0.445\,\log_{10}\frac{t+273.1}{273.1}$$

(3) For relative humidity of vapour over ice

$$\log_{10}\frac{r}{100}=4.56\,\log_{10}\frac{t+273.1}{273.1}-0.83\,\frac{t}{273.1+t}$$

I have verified that these formulae agree with Doctor Washburn's tables at −5°C., −10°C., −30°C., and −100°C. There is only a difference of 0.001 mm., which occurs systematically in the vapour over ice table (e. g. he gets 1.241 at −15°C., whereas I get 1.240).

The agreement with the laboratory results is very remarkable. I never appreciated before the wonderful power of the second law of thermodynamics, on which the Clausius-Clapeyron formula is based.

NOTES AND ABSTRACTS

RESIGNATION OF THE ASSISTANT EDITOR

Dr. B. M. Varney is terminating his connection with the MONTHLY WEATHER REVIEW as of May 14 in order to go to an associate professorship at the University of California at Los Angeles.

W. W. REED ON CLIMATOLOGICAL DATA FOR THE TROPICAL ISLANDS OF THE PACIFIC [1]

This SUPPLEMENT, as its title indicates, presents statistics of temperature, precipitation, relative humidity, cloudiness, and prevailing winds for the single islands and groups of islands of the Pacific.

The data are presented mostly in the form of monthly and annual means and extremes. Monthly and annual totals of precipitation also are given for a group of selected stations at each of which the record covers a period ranging from 20 to 40 years. The statistics have been compiled from existing publications and assembled under a single cover for easy reference.

The author has completed his task in a very satisfactory manner. Copies of the SUPPLEMENT may be obtained from the Superintendent of Documents, Washington, D. C., at the price of 10 cents each. Remittances should be sent direct to that official.—*A. J. H.*

AEROLOGICAL SOUNDINGS BY AIRPLANE IN RELATION TO THE BJERKNES THEORY OF CYCLONES

The final section of a paper under the above title by the Director of the Belgian Meteorological Institute presents the results of three airplane soundings over Belgium. We print a translation of M. Jaumotte's conclusions:

The few cases we have analyzed in this study show perfect agreement between facts and the Bjerknes theory. The cases of the degenerated cyclones prove that the separation of warm and cold air masses persists for a very long time, and that consequently the phenomenon of mixing has but a negligible importance. This is an important argument for the Norwegian school against that of Exner. It is recognized that the two schools have the same point of departure, viz, the juxtaposition of two air masses of different temperatures, considered by Margules as the source of the potential energy which the cyclone partly transforms into kinetic energy. According to Bjerknes the end result is a superposition of the tropical air over the polar; while according to Exner the cyclone brings about a complete mixing of the two masses.

The airplane soundings seem definitely to have settled the question.

But not all the difficulties have been resolved. It is certain that the systematic use of the airplane for exploring the atmosphere will in future make a contribution of the highest importance to the study of the problems which confront us. One may criticize the method at present as being limited by altitude, but on the other hand it possesses the enormous advantage over the *ballon sonde* of not being blind.

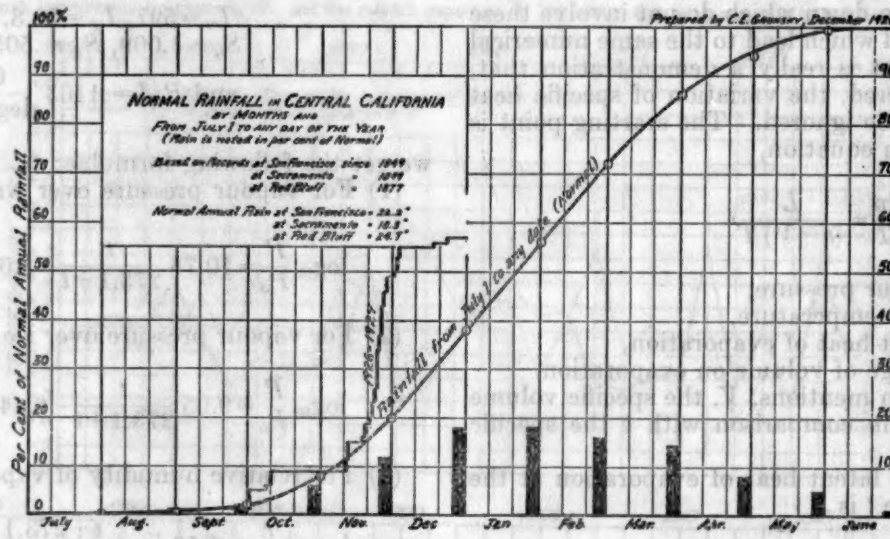
In order to reach its full usefulness, sounding by airplane ought to be carried out by a pilot with a conscientious observer who will carefully note the phenomena observed. It is likewise necessary that the meteorograph be very accurate, and especially that the thermometer record the changes of temperature without lag. It goes without saying that, except in very strongly marked cases, a discontinuity will not be shown if the trace is thickened by vibrations.—*Transl. B. M. V.*

THE SEASONAL RAINFALL TO ANY DATE

By C. E. GRUNSKY

[San Francisco, Calif., January 1, 1927]

A diagram prepared for use in central portions of California as an aid to a quick and dependable determination of the normal rainfall to any day of the climatic year has been found very helpful in making comparison of any season's precipitation with normal.



How such a comparison can be made is shown on the diagram herewith presented. To the base diagram there has been added the mass curve of rainfall for the season 1926–27 from July 1 to December 31 which shows that rainfall at that time for the season 1926–27 was about 57 per cent of the normal annual rainfall, which amount is to be compared with 38 per cent of the normal annual, shown by the curve to be the normal to that date.

When the mass curve of rainfall for individual years is to be plotted on such a base diagram sufficient space above the 100 per cent line should be provided so that there will be room for the possible extreme annual. This in the case of California is somewhat in excess of 200 per cent.

As noted on the diagram the precipitation records at three stations—San Francisco, Sacramento, and Red Bluff—have been used in its preparation and the results apply to any point within an extensive region instead of to the three single stations alone. The normal monthly rainfall, always in percentage of the normal annual, is shown for each month in black. Each of these values is

[1] MONTHLY WEATHER REVIEW SUPPLEMENT No. 28, W. W. Reed.

entered at the end of the respective month. It is their summation which establishes the points on the main or mass-curve of the diagram. The curve though prepared for a region, may nevertheless be accepted as correctly representing the normal precipitation at each one of the three stations on whose composite record it is based, because the values in percentage of normal, at the three several points were in fair correspondence. The composite, in fact, probably better represents normal conditions at each of the stations than do their own particular records because the influence of local sources of error is minimized in the composite.

Where the rainfall year runs with the calendar year the time record on a similar diagram would, of course, begin with January 1 instead of with July 1.

To illustrate the use of the curve the following example may suffice: It is desired to know on December 31 how the rainfall of 7 inches since July 31, 1926, at a point between Sacramento and San Francisco having a normal annual of 15 inches, compares with normal precipitation.

The curve shows that the normal seasonal to December 31 should be 38 per cent of the normal annual precipitation, that is, in this case 38 per cent of 15 inches or 5.7 inches. The rainfall at the point in question was therefore $(7-5.7=)$ 1.3 inches in excess of normal on December 31.

TORNADOES IN ARKANSAS IN MARCH, 1927

By W. C. HICKMON

[U. S. Weather Bureau, Little Rock, Ark.]

Two destructive tornadoes occurred in this State in March, 1927. The first started at 7:30 p. m. of the 17th at the village of Delight, in Pike County, and moved thence some 70 miles northeastward to the border between Saline and Pulaski Counties, covering the distance in about an hour. Eleven persons were killed and 25 injured in this storm.

The second storm originated in Carroll County, south of Eureka Springs, moving thence east to Green Forest and thence east by south to Coin, and thence northeast to Denver, where it disappeared. This storm practically demolished the town of Green Forest, where 22 persons were killed and about 100 injured. Forty-eight houses were destroyed and 132 badly damaged; property loss was large.

The distribution of pressure on the 17th was not such as usually attends a tornado, the V-shaped trough with a southward or southwestward protrusion which Humphreys terms a normal but not invariable condition,[1] was notably missing on the 8 a. m. map; however, the moderate anticyclone to the northwestward was present and the temperature gradient was steep, temperatures of 30° to 36° obtaining in western Oklahoma at 8 a. m., while at Little Rock the temperature was 62°. The 8 p. m. map showed a weak cyclonic condition over the Rockies and the southwest which, on the morning of the 18th, had become a disturbance of wide extent. The temperature gradient was still fairly steep and by 8 p. m. of the 18th the map was much nearer the tornado type.

[1] W. J. Humphreys, The Tornado. Mo. Wea. Rev., Dec., 1926.

A THUNDERSTORM WITH RAIN, HAIL, SLEET, AND SNOW

A thunderstorm at St. Joseph, Mo., on the afternoon of March 19, 1927, was accompanied by rain, hail, sleet, and snow, a most unusual phenomenon. The storm came from the southwest in connection with an area of low barometric pressure central in southern Missouri at 7 p. m. of the 19th. The thunderstorm began at 1:42 p. m., and moderate thunder was heard at frequent intervals until 4:22 p. m. A rather heavy fall of hail began at 2:35 p. m., and continued for three minutes. The hail was preceded, accompanied, and followed by rain, and from 3:41 p. m. to 5:10 p. m., the rain was mixed with sleet, which in turn was followed by light mist. The hailstones were quite uniform in size, about one-fourth inch in diameter, and consisted of soft opaque centers surrounded by clear ice, while the sleet ranged from about the size of large shot to very small particles. The rain with temperature below freezing caused a light covering of glaze, and icicles 1 to 2 inches in length formed on wires and limbs of trees. The amounts of hail and sleet were about equal and when melted gave approximately 0.09 inch of water. During the progress of the thunderstorm snow flurries were noted in the northern portion of the city. The temperature at the time of the hail was 31° F., and while the sleet was falling it stood at 30°. During the storm the wind movement ranged from 7 to 11 miles per hour from the northeast, backing to north, and the barometer remained nearly stationary at slightly below normal. The total precipitation was 0.47 inch.—*W. S. Belden.*

METEOROLOGICAL SUMMARY FOR SOUTHERN SOUTH AMERICA, FEBRUARY, 1927

By J. B. NAVARRETE, Director

[Observatorio del Salto, Santiago, Chile]

February was characterized by increase in the activity of the atmospheric circulation over the far south. In the Central Zone the weather was settled and toward the end of the month the heat of summer began to decline.

The most important depressions were those of the 14th and 23d; the first of these affected the Central Zone to some extent, rain occurring as far north as Valdivia Province. The second depression was more intense; it affected the whole Southern Zone as far north as Concepcion, causing extremely heavy winds and rains. Maximum rainfalls varied between 26 and 46 mm.

The most important anticyclonic régimes developed between the 1st and the 5th, 15th and 22d, and 24th to 28th, and were characterized by general fine weather, and by strong southerly winds between the coasts of Chiloe and Arauco.—*Transl. B. M. V.*

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SOLAR OBSERVATIONS

SOLAR AND SKY RADIATION MEASUREMENTS DURING MARCH, 1927

By HERBERT H. KIMBALL, Solar Radiation Investigations

For a description of instruments and exposures and an account of the method of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1924, **52**: 42, January, 1925, **53**: 29, and July, 1925, **53**: 318.

From Table 1 it is seen that solar radiation intensities averaged close to normal at Washington, D. C., and Madison, Wis., and slightly above normal at Lincoln, Nebr. At Lincoln, at 10:08 a. m. of the 21st a measured intensity of 1.54 gram calories per minute per square centimeter is only 1 per cent less than the highest midday intensity ever measured at that station in March.

Table 2 shows a deficiency in the total solar radiation received on a horizontal surface from the sun and sky at the three stations for which normals have been determined.

Skylight polarization measurements made at Madison on 16 days give a mean of 61 per cent with a maximum of 69 per cent on the 1st. These are close to normal values for March at Madison. At Washington, measurements made on 11 days give a mean of 54 per cent with a maximum of 68 per cent on the 4th. The maximum is above and the mean is below the corresponding averages for March at Washington.

TABLE 1.—*Solar radiation intensities during March, 1927*

[Gram-calories per minute per square centimeter of normal surface]

WASHINGTON, D. C.

Date	Sun's zenith distance										
	8 a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
Mar. 3	2.49		1.00	1.14	1.29						1.78
4	2.06	0.95	1.06	1.21	1.37	1.55	1.20	1.04	0.94	0.80	1.88
5	2.87	0.91	1.04	1.18	1.32	1.48					2.62
10	3.30	0.71	0.83	0.97	1.11	1.40	0.97	0.74	0.62		3.00
11	4.17						1.21				4.75
15	5.79		0.59	0.76	0.97						6.50
16	6.27	0.51	0.66	0.83	1.10	1.37	1.26	1.02	0.79	0.61	7.04
17	7.29		0.65	0.82	0.95						9.83
25	3.81				0.88	1.12					3.99
29	3.63		0.58	0.69	0.96						3.81
Means		0.77	0.80	0.95	1.11	1.38	1.16	0.93	0.78	(0.70)	
Departures		+0.06	±0.00	+0.01	−0.04	−0.05	+0.03	−0.01	−0.02	+0.01	

MADISON, WIS.

Date	8 a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
Mar. 2	1.60			1.29	1.42	1.56	1.43				1.88
3	2.06	1.13	1.20	1.31	1.43	1.57	1.45				1.78
8	3.63		1.07	1.18	1.36	1.57					3.15
9	3.63				1.18	1.54					4.37
14	5.56						1.22				5.56
15	4.75				1.11		1.11				6.76
17	4.57				1.31						3.99
22	3.00		1.05	1.16							3.00
28	3.15				1.19						2.49
30	4.57				1.20	1.48					4.57
Means		(1.13)	1.11	1.24	1.28	1.54	1.30				
Departures		+0.14	+0.07	+0.06	−0.04		±0.00				

LINCOLN, NEBR.

Date	8 a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
Mar. 2	2.36			1.17	1.37	1.53	1.20	1.11	1.01		1.88
3	1.96	0.84	0.96	1.14	1.36						2.36
4	3.15	0.53	0.66	0.83	1.05	1.29					4.37
7	4.37					1.59		1.26	1.11	0.97	3.45
8	3.63	0.85	1.00	1.19	1.38	1.61	1.32	1.15	1.00	0.87	3.30
9	3.99				1.26						4.37
14	4.37	0.75			1.19		1.36	1.17	1.05	0.94	4.95
21	3.63			1.23	1.43	1.65	1.39	1.13	0.75		2.62
26	2.87		1.05	1.20	1.36	1.54					2.87
Means		0.74	0.92	1.13	1.30	1.54	1.32	1.16	0.98	0.93	
Departures		−0.12	−0.03	+0.03	+0.01		+0.03	+0.07	+0.03	+0.10	

* Extrapolated.

TABLE 2.—*Solar and sky radiation received on a horizontal surface*

[Gram-calories per square centimeter of horizontal surface]

Week beginning	Average daily radiation						Average daily departure from normal		
	Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Washington	Madison	Lincoln
	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
Feb. 26	302	284	322	228	304		+8	+14	−21
Mar. 5	319	236	281	199	243		+9	−42	−66
12	333	313	298	210	244		−4	+7	−79
19	225	205	328	136	240	*499	−132	−105	−82
26	169	322	255	205	217	371	−178	−17	−157
Deficiency since first of year on Apr. 1							−3,766	−1,407	−3,338

*Four-day mean.

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. Edwin T. Pollock, Superintendent U. S. Naval Observatory]

[Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, and Mount Wilson Observatories]

Date	Eastern standard civil time	Heliographic Longitude	Heliographic Latitude	Area * Spot	Area * Group
1927	h. m.	°	°		
Mar. 1 (Naval Observatory)	11 31	−44.0	+23.0		62
		−13.5	−18.0	123	
		+40.5	+13.5		93
		+44.5	−23.0		31
Mar. 2 (Harvard)	12 20	−27.0	+27.0		212
		+2.0	−15.0	242	
Mar. 3 (Naval Observatory)	11 44	−72.0	−19.0	185	
		−71.0	+10.0		62
		−17.0	+23.5		93
		+13.0	−17.5	123	
		+28.0	−18.0		46
		+62.0	+13.5		31
Mar. 4 (Naval Observatory)	11 48	−59.5	−13.5	247	
		−59.0	+10.0	62	
		−3.0	+23.5		93
		+25.5	−17.5		154
		+41.5	−17.5		62
Mar. 5 (Naval Observatory)	11 50	−49.0	+10.0		62
		−47.0	−20.0	185	
		−45.5	−13.0	31	
		+12.5	+22.0		77
		+39.0	−18.0	108	
		+54.0	−17.5		123
Mar. 6 (Naval Observatory)	11 42	−38.0	−20.5	46	
		−32.5	−13.5	154	
		−32.0	+19.5		31
		−31.5	+10.0	31	
		−31.0	+24.5	31	
		+20.0	+21.5		93
		+28.0	−18.0		
		+52.0	−17.0	123	
		+71.0	−17.0	62	
Mar. 7 (Naval Observatory)	13 40	−22.0	−22.5		62
		−19.5	+18.0		46
		−19.5	−15.5	154	
		−18.5	+10.0		31
		−18.0	+27.0		31
		+33.0	+22.0		108
		+42.5	−15.5	93	
		+66.0			
Mar. 8 (Naval Observatory)	11 50	−24.0	+10.0		10
		−11.0	−22.0		62
		−7.5	−15.5	154	
		−5.0	+19.0		46
		−5.0	+10.0	42	
		+47.0	+26.0		31
		+56.0	+22.0		62
		+62.5	−19.0	37	
		+70.0	+7.5		123
		+77.5	−17.5	123	
Mar. 10 (Naval Observatory)	11 49	−34.0	−20.0		
		−32.5	+16.5		15
		+18.5	−21.0		108
		+19.0	−14.5		31
		+19.0	−21.0	139	
		+77.5			93
Mar. 11 (Naval Observatory)	11 46	−78.5	−9.5	154	
		−19.5	+15.5		62
		−19.0	+15.5		262
		+29.0	−21.0		62
		+31.5	−14.5	154	
Mar. 12 (Naval Observatory)	11 42	−65.0	−9.5	154	
		−5.0	+15.5		216
		−5.0	+15.5		46
		+44.5	−14.0		139
Mar. 13 (Naval Observatory)	11 41	−78.0	+17.5	123	
		−71.5	+31.0	154	
		−52.0	−9.5	185	
		+7.5	+15.5		154
		+7.5	−18.0		15
		+50.5	+17.5		18
		+59.0	−12.5	139	
		+59.5	−18.0		31
Mar. 14 (Harvard)	11 34	−69.0	−9.0		152
		−60.0	+18.0	136	
		−55.0	+32.0		409
		−34.0	−7.0	152	
		+29.0	+17.0		76
		+75.0	−10.0	182	
Mar. 15 (Naval Observatory)	11 45	−64.0	−9.0		247
		−57.0	+35.0		679
		−49.5	+18.0	123	
		−45.0	+31.0	154	
		−26.0	−9.5	154	
		−24.0	+19.5		31
		+37.5	+15.5		123
		+85.0	−12.5	154	
Mar. 16 (Naval Observatory)	11 46	−55.5	−11.0		31
		−47.0	−8.0		123
		−44.0	+35.0		710
		−37.0	+18.0	123	
		−31.0	+31.0	154	
		−12.0	−9.0	139	
		−9.5	+19.0		123
		+51.0	+15.5		97

* Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere.

Positions and areas of sun spots—Continued

Date	Eastern standard civil time		Heliographic		Area	
			Longitude	Latitude	Spot	Group
1927	h.	m.	°	°		
Mar. 17 (Naval Observatory)	11	57	−66.0	−10.0	....	31
			−54.0	−10.5	....	31
			−42.0	−11.0	....	31
			−33.5	−8.0	....	123
			−32.0	+34.0	....	586
			−22.5	+18.0	108	....
			−19.0	+31.0	154	....
			+1.0	−9.0	123	....
			+3.5	+18.5	....	77
			+68.0	+16.0	....	93
Mar. 18 (Naval Observatory)	11	42	−52.0	−10.0	....	15
			−40.0	−10.5	....	108
			−19.5	−8.0	....	62
			−18.0	+34.0	....	432
			−10.0	+18.0	108	....
			−7.5	+31.0	154	....
			+14.5	−9.0	123	....
			+16.0	+18.5	....	216
			+82.0	+15.0	62	....
Mar. 19 (Naval Observatory)	11	33	−38.0	−9.5	....	10
			−26.0	−10.5	....	185
			−7.5	−9.0	....	46
			−5.0	+34.0	....	463
			+3.5	+18.0	93	....
			+7.5	+30.5	154	....
			+28.5	−9.5	....	93
			+29.5	+18.5	....	185
Mar. 20 (Naval Observatory)	12	38	−29.5	−10.5	....	46
			−11.0	−10.5	....	154
			+2.0	+15.0	15	....
			+7.0	+34.5	....	494
			+7.5	−9.5	31	....
			+17.5	+18.0	123	....
			+19.5	+30.5	....	216
			+42.0	−9.5	62	....
			+42.5	+18.5	....	185
Mar. 21 (Mount Wilson)	14	45	−22.5	+8.0	....	16
			−15.0	+4.0	2	....
			−14.0	−11.0	....	5
			+3.5	−11.5	....	91
			+18.0	−12.0	....	13
			+25.0	+33.0	....	472
			+32.5	+17.0	106	....
			+53.0	−9.5	....	38
			+55.0	+18.0	....	41
Mar. 22 (Naval Observatory)	11	45	+15.0	−11.0	....	139
			+32.0	+35.0	....	370
			+33.5	−10.0	31	....
			+44.0	+18.0	123	....
			+44.5	+31.0	185	....
			+67.5	+18.0	....	185
			+69.5	−9.0	31	....
Mar. 23 (Naval Observatory)	13	16	−44.0	−17.0	....	49
			+30.0	−11.5	....	108
			+44.0	+35.0	....	216
			+58.5	+17.5	62	....
			+59.0	+31.0	139	....
Mar. 24 (Naval Observatory)	12	55	−65.0	+11.0	62	....
			−29.0	−17.5	....	31
			+45.0	−11.0	....	46
			+58.0	+34.0	....	154
			+70.0	+30.5	123	....
			+71.0	+17.5	108	....
Mar. 25 (Naval Observatory)	11	45	−52.0	+10.5	31	....
			−15.0	−17.0	....	15
			+10.5	−9.0	....	46
			+55.0	−12.0	....	31
			+69.5	+35.0	....	123
			+85.0	+17.5	154	....
			+86.0	+30.5	154	....
Mar. 26 (Naval Observatory)	13	58	−57.5	−41.0	....	31
			−37.5	+11.0	31	....
			−11.5	−15.0	10	....
			+24.0	−9.5	....	62
Mar. 27 (Naval Observatory)	13	24	−24.0	+11.0	31	....
			+38.0	−9.5	....	62
			+44.0	+15.0	....	62
Mar. 28 (Naval Observatory)	14	8	No spots.			
Mar. 29 (Naval Observatory)	11	43	−78.0	+17.5	154	....
			−7.5	−24.0	....	62
Mar. 31 (Naval Observatory)	13	41	−80.0	+12.0	309	....
			−49.5	−13.5	....	15
			−49.0	+17.5	108	....
			−2.5	+11.0	....	15

AEROLOGICAL OBSERVATIONS

By L. T. SAMUELS

With the exception of the lower levels at Due West and the 4,000 and 4,500 meter levels at Ellendale, all of the mean free-air temperatures for March were above normal. (See Table 1.) The largest departures occurred in the upper levels at Broken Arrow and Royal Center. As a rule the resultant winds contained an excess of southerly component over the normal wherever the mean temperatures were above normal. (See Table 2.) Relative humidity and vapor pressures were mostly above normal, the largest departures of both elements occurring at Groesbeck.

A conspicuous feature of the resultant winds as shown by pilot-balloon observations was the pronounced north component at 2,000 meters above San Francisco and Los Angeles, whereas at some 30 other stations widely distributed over the country an equally marked west component was found at the same level. At 4,000 meters this northerly component obtained over the north Pacific coast as well, the resultants at Medford and Seattle being the same at this level as at San Francisco and Los Angeles, while at stations to the east the west component continued to predominate. An unusually large number of observations reaching very high altitudes at Medford indicated a steady increase in the north component to at least 9,000 meters where the resultant was N. 9° W. 13.5 m. p. s.

Two kite flights made at Due West on the 1st and 2d were of more than ordinary interest in that they were made during a snowfall. On the 1st this station was situated in the northeast quadrant of a low-pressure area approaching from the southwest. The kite flight showed a lapse rate of 0.47° C. per 100 meters from the ground to 900 meters above, then an inversion with a lapse rate of −0.47° C. to 1,500 meters, the maximum altitude reached. The entire air column including the inversion layer was saturated, the base of the St.-Cu. clouds being 100 meters above ground. The wind veered from east-northeast at the surface to southeast at the highest altitude. A moderate to light snowfall continued throughout the flight. Owing to the limited height reached it is, of course, not known whether the inversion continued to an even higher elevation or whether the lapse rate changed to positive and became relatively steep.

If we assume the latter, the precipitation can be explained by the overrunning of the warm saturated air within the inversion by a cold current above. Such a condition might obviously result in convection in these upper levels and in the case of saturated air produce precipitation as well. On the other hand it may be assumed that the warm air observed within the inversion had been forced up over the colder air lying nearest the ground. This forced ascent might, of course, result in sufficient cooling to produce condensation and precipitation.

By the next morning this LOW's center lay just off the Carolina coast and Due West was in its west quadrant. The kite flight at this time showed practically the same temperatures and lapse rate to 900 meters above ground, the latter being 0.43° C. per 100 meters as compared to 0.47° C. on the day preceding. For the next 600 meters, however, the inversion which was found on the 1st was now replaced by colder air wherein the lapse rate was 0.45° C. Thus at 1,500 meters above ground the temperature was 6° C. lower on the 2d than on the 1st. The winds on the 2d backed from north at the surface to northwest at 1,500 meters above. Light to moderate snow fell during the ascent of this flight but before it ended the St. clouds had broken, revealing A.Cu. from the northwest and the precipitation ended.

It seems probable that the warm moisture-laden air transported from the southeast, which was observed within the inversion layer on the 1st, under-ran the cold air found above 1,500 meters on the 2d, assuming the temperature above this level had not changed appreci-

ably during the two days. The precipitation ended, however, since the source of the air changed from the low to the high pressure area.

In connection with this same depression it is found that Groesbeck on the 1st, while situated to the west of the LOW's center, was apparently under the influence of the approaching HIGH. A kite flight made at this station showed a lapse rate from the ground to 550 meters above, of 0.98° C. per 100 meters, above which was a strong inversion wherein the lapse rate was −0.79° C. to 1,870 meters above ground. It is not likely that this inversion would have existed had this station been under the influence of the LOW, since this condition is more characteristic of the front of a HIGH. While the temperatures below the base of the inversion were *lower* at Groesbeck than at Due West on the morning of the 1st yet within the inversion they were several degrees higher, notwithstanding the fact that the winds *within* the inversion were northwesterly at Groesbeck and southeasterly at Due West.

The highest kite flight ever made at the Royal Center station was obtained on the 16th when an altitude of 5,910 meters (S. L.) was reached. This record was obtained between an area of high pressure to the east and low pressure to the west.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during March, 1927*

TEMPERATURE (°C.)

Altitude (m.) m. s. l.	Broken Arrow, Okla. (233 m.) Mean	Departure from 9-yr. mean	Due West, S. C. (217 m.) Mean	Departure from 7-yr. mean	Ellendale, N. Dak. (444 m.) Mean	Departure from 10-yr. mean	Groesbeck, Tex. (141 m.) Mean	Departure from 9-yr. mean	Royal Center, Ind. (225 m.) Mean	Departure from 9-yr. mean	Washington, D. C.[1] (7 m.) (mean)
Surface	10.5	+0.5	11.3	−0.9	−0.6	+1.9	14.6	+1.4	6.0	+1.9	11.2
250	10.4	+0.5	11.1	−0.8			13.9	+1.3	5.8	+1.9	9.5
500	8.9	+0.8	9.4	−0.7	−1.0	+1.7	12.3	+0.9	3.9	+2.0	7.9
750	7.7	+0.8	8.3	−0.4	−2.2	+1.3	11.0	+0.5	2.6	+1.9	7.0
1,000	6.7	+0.6	7.3	−0.2	−3.0	+0.9	10.4	+0.6	1.9	+1.9	6.2
1,250	5.9	+0.4	6.6	+0.2	−3.6	+0.9	10.0	+0.8	1.3	+2.0	5.2
1,500	5.4	+0.6	5.6	+0.4	−4.3	+0.8	9.7	+1.1	0.7	+2.1	4.1
2,000	4.1	+1.0	3.1	+0.1	−6.3	+0.5	9.4	+2.2	−1.1	+1.8	2.3
2,500	2.2	+1.4	1.4	+0.6	−8.8	+0.3	7.2	+2.1	−3.2	+1.9	0.1
3,000	0.0	+1.7	−0.3	+1.0	−11.5	+0.3	4.0	+1.4	−5.3	+2.1	−2.6
3,500	−1.9	+2.4	−2.9	+0.8	−14.1	+0.3	1.1	+1.2	−7.8	+2.1	−3.8
4,000	−4.1	+3.2			−17.2	−0.1	−1.7	+1.3	−10.2	+2.2	−6.0
4,500	−6.7	+3.4			−20.4	−0.4	−4.9	+0.7	−13.0	+2.2	
5,000					−22.4	+0.4			−16.4	+2.2	

[1] Naval Air Station, Anacostia, D. C.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during March, 1927*—Continued

RELATIVE HUMIDITY (%)

Altitude (m.) m. s. l.	Broken Arrow, Okla. (233 m.) Mean	Departure from 9-yr. mean	Due West, S. C. (217 m.) Mean	Departure from 7-yr. mean	Ellendale, N. Dak. (444 m.) Mean	Departure from 10-yr. mean	Groesbeck, Tex. (141 m.) Mean	Departure from 9-yr. mean	Royal Center, Ind. (225 m.) Mean	Departure from 9-yr. mean	Washington, D. C. (7 m.) (mean)
Surface	65	+1	73	+10	74	+1	75	+5	73	+1	64
250	65	+1	73	+10			75	+6	73	+1	66
500	62	−1	74	+11	73	+1	75	+8	73	+2	67
750	62	0	72	+10	69	+2	74	+10	73	+4	65
1,000	63	+2	71	+9	66	+3	72	+12	68	+2	64
1,250	63	+5	69	+7	62	+3	66	+10	64	+1	61
1,500	58	+4	69	+7	59	+2	59	+7	59	−1	61
2,000	50	+3	67	+9	59	+4	42	−1	52	−5	52
2,500	45	+2	57	+5	65	+10	36	−3	46	−9	45
3,000	45	+4	43	−3	68	+12	42	+5	50	−5	40
3,500	40	+1	40	−3	61	+6	46	+10	52	−1	31
4,000	38	0			58	+5	47	+9	52	0	23
4,500	36	0			58	+6	45	+5	52	−3	
5,000					51	0			54	−3	

VAPOR PRESSURE (mb.)

Altitude (m.) m. s. l.	Broken Arrow Mean	Departure from 9-yr. mean	Due West Mean	Departure from 7-yr. mean	Ellendale Mean	Departure from 10-yr. mean	Groesbeck Mean	Departure from 9-yr. mean	Royal Center Mean	Departure from 9-yr. mean	Washington, D. C. (mean)
Surface	8.34	+0.10	10.53	+0.91	4.30	+0.45	13.48	+2.07	7.05	+0.82	8.93
250	8.24	+0.07	10.40	+0.93			13.00	+2.11	6.97	+0.85	8.29
500	7.13	−0.12	9.56	+1.06	4.17	+0.43	11.91	+2.14	6.24	+0.97	7.61
750	6.57	+0.02	8.68	+0.97	3.57	+0.31	10.84	+2.00	5.76	+1.03	6.99
1,000	6.32	+0.26	7.83	+0.77	3.17	+0.22	10.10	+2.16	5.16	+0.90	6.35
1,250	5.89	+0.39	7.20	+0.74	2.80	+0.10	8.92	+1.94	4.58	+0.74	5.55
1,500	5.21	+0.32	6.71	+0.91	2.55	+0.06	7.58	+1.50	3.96	+0.48	5.09
2,000	3.78	+0.05	5.19	+0.68	2.17	+0.05	4.76	+0.38	3.16	+0.22	3.68
2,500	2.72	−0.21	3.55	+0.22	2.00	+0.23	3.49	+0.14	2.37	−0.10	2.49
3,000	2.14	−0.22	2.02	−0.27	1.64	+0.22	3.23	+0.57	2.17	+0.06	1.45
3,500	1.63	−0.23	1.56	−0.09	1.13	0.00	2.92	+0.75	1.85	+0.25	0.25
4,000	1.01	−0.38			0.74	−0.16	2.70	+0.80	1.60	+0.31	
4,500	0.63	−0.47			0.50	−0.23	2.41	+0.62	1.36	+0.28	
5,000					0.32	−0.29			1.24	+0.28	

TABLE 2.—*Free-air resultant winds (m. p. s.) during March, 1927*

Altitude (m.) m. s. l.	Broken Arrow, Okla. (233 meters) Mean Dir.	Vel.	9-year mean Dir.	Vel.	Due West, S. C. (217 meters) Mean Dir.	Vel.	7-year mean Dir.	Vel.	Ellendale, N. Dak. (444 meters) Mean Dir.	Vel.	10-year mean Dir.	Vel.
Surface	S. 18° W.	2.5	S. 14° W.	1.9	S. 62° E.	0.8	S. 73° W.	1.7	N. 74° W.	1.2	N. 43° W.	2.0
250	S. 18° W.	2.5	S. 16° W.	2.0	S. 81° E.	0.9	S. 70° W.	1.8				
500	S. 25° W.	3.2	S. 19° W.	3.2	S.	1.4	S. 73° W.	3.1	N. 81° W.	1.3	N. 49° W.	2.0
750	S. 27° W.	4.0	S. 23° W.	4.0	S. 37° W.	1.8	S. 75° W.	4.3	N. 80° W.	1.9	N. 66° W.	2.5
1,000	S. 35° W.	4.3	S. 36° W.	4.7	S. 48° W.	3.9	S. 74° W.	5.5	S. 84° W.	2.1	N. 74° W.	3.0
1,250	S. 53° W.	5.0	S. 49° W.	5.4	S. 45° W.	5.4	S. 74° W.	6.8	S. 80° W.	3.1	N. 74° W.	4.0
1,500	S. 58° W.	6.4	S. 65° W.	5.9	S. 49° W.	7.1	S. 76° W.	8.5	S. 81° W.	3.3	N. 75° W.	5.1
2,000	S. 62° W.	7.8	S. 78° W.	7.0	S. 58° W.	8.9	S. 80° W.	10.8	S. 85° W.	4.4	N. 74° W.	6.9
2,500	S. 75° W.	8.2	S. 88° W.	8.3	S. 67° W.	9.5	S. 87° W.	12.1	S. 77° W.	6.5	N. 74° W.	9.1
3,000	S. 65° W.	10.1	N. 89° W.	9.7	S. 72° W.	13.8	S. 83° W.	14.3	N. 87° W.	9.7	N. 75° W.	11.1
3,500	S. 68° W.	10.3	S. 82° W.	10.6	S. 67° W.	18.3	S. 85° W.	14.9	S. 81° W.	12.3	N. 81° W.	12.8
4,000	S. 77° W.	13.7	S. 78° W.	11.4	S. 22° W.	12.0	S. 88° W.	15.7	S. 58° W.	15.0	N. 86° W.	14.0
4,500	S. 82° W.	16.2	S. 69° W.	13.4					W.	17.0	N. 87° W.	14.4
5,000	W.	21.0	S. 70° W.	8.8					W.	21.0	N. 84° W.	16.0

Altitude (m.) m. s. l.	Groesbeck, Tex. (141 meters) Mean Dir.	Vel.	9-year mean Dir.	Vel.	Royal Center, Ind. (225 meters) Mean Dir.	Vel.	9-year mean Dir.	Vel.	Washington, D. C. (34 meters) Mean Dir.	Vel.	7-year mean Dir.	Vel.
Surface	S. 11° W.	2.0	S. 6° E.	0.9	S. 31° W.	2.0	S. 49° W.	1.7	N. 23° W.	1.5	N. 46° W.	1.6
250	S. 9° W.	2.6	S. 7° E.	1.6	S. 30° W.	2.1	S. 45° W.	1.8	N. 54° W.	2.2	N. 77° W.	3.2
500	S. 12° W.	4.2	S. 5° E.	3.1	S. 42° W.	3.1	S. 54° W.	4.1	N. 69° W.	3.4	N. 77° W.	5.0
750	S. 24° W.	5.1	S. 20° W.	3.7	S. 43° W.	4.0	S. 60° W.	5.2	N. 65° W.	4.0	N. 72° W.	6.1
1,000	S. 33° W.	6.0	S. 36° W.	4.4	S. 49° W.	4.8	S. 66° W.	6.0	N. 59° W.	4.5	N. 68° W.	6.8
1,250	S. 40° W.	6.8	S. 45° W.	5.0	S. 61° W.	5.4	S. 74° W.	7.1				
1,500	S. 39° W.	7.5	S. 50° W.	5.3	S. 62° W.	6.8	S. 81° W.	8.1	N. 62° W.	5.5	N. 66° W.	8.3
2,000	S. 50° W.	7.7	S. 62° W.	6.5	S. 77° W.	7.8	S. 85° W.	9.4	N. 62° W.	6.8	N. 69° W.	9.9
2,500	S. 47° W.	8.6	S. 66° W.	8.6	S. 76° W.	10.0	S. 89° W.	10.5	N. 48° W.	7.2	N. 66° W.	9.3
3,000	S. 58° W.	8.1	S. 71° W.	9.4	S. 72° W.	11.9	W.	13.2	N. 54° W.	9.2	N. 72° W.	11.1
3,500	S. 72° W.	10.8	S. 74° W.	12.4	S. 74° W.	12.0	S. 88° W.	15.1	N. 72° W.	10.6	N. 81° W.	12.6
4,000	S. 63° W.	12.2	S. 69° W.	14.1	S. 66° W.	9.8	S. 83° W.	13.4	N. 53° W.	11.4	N. 69° W.	12.1
4,500	S. 84° W.	11.8	S. 83° W.	13.1	S. 79° W.	9.4	S. 85° W.	11.2			N. 72° W.	13.5
5,000					S. 71° W.	12.7	S. 71° W.	12.7			N. 75° W.	13.4

WEATHER IN THE UNITED STATES

GENERAL CONDITIONS

The month was warmer than usual over the greater part of the United States. The outstanding feature, judged by its effect in contributing to what appears to be the greatest flood in a century in the lower Mississippi, was the heavy rains of the month in the Ohio, Mississippi, and the lower Missouri Valleys, portions of which received from 100 to 300 per cent of the normal March precipitation. The heavy rains were confined to the interior valleys and the middle plateau and Rocky Mountain regions. Large areas in both the Atlantic and Pacific drainage had a pronounced shortage in precipitation. The usual details follow.—*A. J. H.*

CYCLONES AND ANTICYCLONES

By W. P. Day

The great HIGH, which had been developing over the Canadian Northwest during the last days of February, moved slowly southeast during the first five days of March, and thereafter, until the 18th, high-pressure areas were of slight intensity and largely of Pacific origin. Between the 18th and the end of the month several HIGHS of the Hudson Bay, Alberta, and North Pacific types of moderate intensity were observed. There were 13 HIGHS in all.

Twenty-one low-pressure areas were tracked, but the only important storm occurred during the first three days of the month, a development over the Gulf, which moved northeast along the Atlantic coast in connection with the great HIGH over the interior.

THE WEATHER ELEMENTS

By P. C. Day, In Charge of Division

PRESSURE AND WINDS

March, 1927, had frequent changes in barometric pressure over the central and northern districts, but they were usually of only moderate importance; hence the winds were mainly light, and the stormy, blustery weather commonly associated with March was notably lacking, not only in the areas referred to above but in most other districts as well.

March opened with cyclonic conditions near the middle Gulf coast, attended by precipitation over an extensive area to the northward, and snow was falling over the northern portion of the area from the middle Missouri Valley southeastward to the elevated districts of the Carolinas and Georgia. By the morning of the 2d the storm had moved to the North Carolina coast, greatly increased in intensity, and unusually heavy snow for the region and season had fallen over the southern Appalachian Mountains and eastward nearly to the coast. The depths in North Carolina were particularly heavy, ranging up to 2 feet or more, in some instances the greatest depths ever recorded. High winds accompanied the storm as it approached the coast and much drifting of snow and interruption to traffic resulted for a short period. This storm moved northeastward into the ocean during the 3d, and snowfall did not extend north of the southern Chesapeake Bay region. The precipitation associated with this storm was generally heavy over the Gulf and South Atlantic States, New Orleans reporting more than 4 inches on the morning of the 1st.

The next important cyclone originated near the middle Rio Grande Valley on the 6th, and by the 7th had moved to the middle Mississippi Valley, attended by local thunderstorms and some heavy rains in northern Texas and portions of Arkansas and near-by areas. By the morning of the 8th the center had moved to the St. Lawrence Valley, and heavy rains had continued over portions of the area referred to above and extended into the Ohio Valley and near-by areas, while lighter falls had occurred over most other districts from the Mississippi River eastward, save along the South Atlantic and east Gulf coasts.

On the 9th and 10th a slight barometric depression passed over the Gulf and South Atlantic States attended by some heavy rains, and at the same time showers with local snows were rather general in the plateau region and to the westward. On the morning of the 11th a storm of moderate intensity was central over northwest Texas and snow was falling over much of the middle Rocky Mountains, and local heavy rains had occurred in western Kansas, the rain area extending into the southern plains. During the following two days the storm advanced through the middle Missouri Valley to the upper lake region and heavy rains occurred over extensive areas in the Mississippi and Ohio Valleys. At Memphis, Tenn., the total fall on the 11th and 12th was nearly 6 inches, and amounts from 1 to 2 inches or more occurred at numerous points in the area of heavy precipitation.

Some heavy rains occurred over a narrow area from northern Texas to the lower Lakes on the 18th and 19th. On the latter date a well-defined cyclone was central over New Mexico, whence it moved through the middle Mississippi Valley to the lower Lakes and North Atlantic coast during the following three days, attended by heavy rains over much of the central valleys and general rains over most of the country to the eastward, with more or less snow, glaze, or sleet over the northern portion of the precipitation area.

The last decade had rather frequent showers in the central valleys and some eastern districts, but the amounts were mainly small, except on the last day, when an extensive cyclone moving from the middle plateau was central over eastern Colorado and precipitation had extended well to the eastward of the center of low pressure. Heavy rains had fallen in the middle Mississippi Valley, and by the morning of April 1 the storm was central over eastern Missouri, attended by additional heavy rains in the middle Mississippi Valley and near-by areas, adding greatly to the flood conditions already threatening in that region. This storm moved eastward toward the Middle Atlantic States during the 2d, but with diminished precipitation.

Over the Pacific Coast States cyclonic storms were markedly infrequent and unimportant, and there was mainly little precipitation at any time during the month.

The most important anticyclone of the month covered the western plains at the beginning, and as it moved eastward, brought for a few days the coldest weather of the month to all districts from the Great Plains eastward. This was particularly effective in lowering the temperature over the Gulf and South Atlantic States, where freezing temperature extended to the coast lines and into the interior of the Florida Peninsula, considerable damage to vegetation occurring as far south as the Everglades. On account of rain and snow having recently preceded the change to colder weather, much damage resulted in the early fruit districts of the Southeast from water freezing in the open blossoms.

A second important anticyclone moved into the Dakotas on the 19th and brought decidedly cold weather over the plains region and southern districts during the following two or three days. This anticyclone closely followed a precipitation area, which, moving northeastward over the central valleys, caused considerable snow, sleet, and glaze, as indicated elsewhere.

Mild anticyclonic conditions existed during much of the month over the eastern districts, and the average pressure for the month was highest and materially above normal over the Southeastern States, and generally lowest in the Southwest, though the average pressure there was mainly slightly above normal, and it was above in all other districts, save locally in North Dakota and the upper Missouri Valley and the adjacent areas of Canada.

Compared with February the average pressure was higher from the Mississippi Valley eastward and over the Pacific coast from central California to Washington and in Idaho. It was lower over the Great Plains and Rocky Mountains and most of the plateau region.

Local high winds were somewhat frequent during the first two decades, but there were few of these during the last third, and they were mainly absent from the Pacific coast region during the month. The details of the more important local storms appear at the end of this section.

TEMPERATURE

The unusual warmth that characterized the preceding months of January and February persisted throughout much of March from the Rocky Mountains eastward; indeed, over the Gulf States unusual warmth has continued since December, 1926, inclusive.

The month opened with decidedly cold weather over the Great Plains, zero temperatures extending southward into Oklahoma and northern Texas and freezing well toward the southern portion of the last-named State. This cold area gradually spread eastward during the following few days, carrying the line of freezing weather to the Gulf and South Atlantic coasts on the 2d and 3d and into the Florida Peninsula on the 3d and 4th.

Following this cold period there was a quick return to warmer, and by the 5th temperatures were above normal over much of the country from the Rocky Mountains eastward, though it still continued cool for the season over the more southeastern districts. With occasional slight variations from day to day, temperatures remained above normal almost continuously until near the end of the second decade, though over the more eastern portions unusual warmth continued into the beginning of the last decade.

Beginning with the 18th, colder weather set in over the upper Missouri Valley and during the following two days advanced southerly to the west Gulf States, freezing temperatures extending into western and central Texas, with the coldest weather of the month over most of the Rocky Mountain States. This cold area moved eastward during the following two or three days, bringing frosts and freezing temperatures to the central portions of the Gulf and South Atlantic States. During the remaining portions of the last decade the temperatures were mainly lower than normal over the entire eastern half of the country.

From the Rocky Mountains westward the temperatures were mainly below normal and there were frequent sharp falls over the plateau and Rocky Mountain States. No damaging cold occurred over the Pacific Coast States.

Some unusual warmth occurred over the central and eastern districts during the middle and latter portions of the second decade, and the highest temperatures ever observed so early in the month were recorded locally on the 16th to 18th in the upper lake region, Ohio Valley, and Southeastern States.

The warmest periods were observed in the upper Missouri Valley on the 14th and on successive dates to the eastward until the 19th and 20th as the warm area moved toward the Atlantic coast, though along the immediate coast the highest temperatures were observed about the 16th to 18th. West of the Rocky Mountains the warmest dates were mainly near the middle of the last decade.

The coldest periods were from the 1st to 4th over the Great Plains and thence eastward to the Atlantic coast, the morning of the 3d bringing severe and damaging frosts to nearly all parts of the Gulf and South Atlantic States and over much of the Florida Peninsula, early vegetables being severely injured in the Everglades district. In the Rocky Mountain region the lowest temperatures were about the 20th and 21st, but over the plateau and Pacific Coast States they were mostly during the early part of the month.

The average temperature for the month was above normal in practically all portions from the Missouri and Mississippi drainage areas eastward to the Atlantic coast and over the whole of Canada, as far as available observations disclose. The warmest portions, from 5° to 10° or more above, covered the area from the Missouri Valley eastward to New England and along the entire southern Canadian border, Winnipeg, Manitoba, reporting a positive departure in excess of 15°. From the Rocky Mountain region westward the average temperature was mostly lower than normal, though generally to a small extent only, slight excesses occurring in the central plateau.

PRECIPITATION

The rainfall was fairly well distributed in point of time, but very unevenly as to amounts.

In the central valleys, and notably in the States immediately bordering on the Mississippi River, precipitation was frequent and greatly in excess of the normal for March, particularly in the middle and southern portions, and at the close of the month that river was above flood stages from Cairo southward. Generally speaking, precipitation was in excess of normal, but to a much less degree, over nearly the entire Mississippi, Missouri, and Ohio watersheds, and in the middle Rocky Mountain and plateau regions as well. Precipitation was less than normal, but generally sufficient for current needs, over the east Gulf and Atlantic Coast States, the month being quite dry over the middle Atlantic coast section, and particularly so in portions of New Jersey where it was the driest March of record. Precipitation was below normal in the far Southwest, over the Pacific Coast States, and along the northern border from Washington to North Dakota.

SNOWFALL

The outstanding feature of the snowfall distribution was the large amount received on the 1st and 2d over portions of North Carolina and near-by areas, which, as stated elsewhere, was unusual not only as to the depths attained but for the lateness of occurrence in the locality referred to. Large local amounts were received in the Black Hills region at the close of March and the beginning of April, Rapid City reporting a depth of more than 18 inches, apparently the greatest single fall of record.

Considerable snow, sleet, or glaze occurred over the eastern portions of Nebraska and South Dakota and thence to near the southern end of Lake Michigan on the 19th and 20th, attended by heavy local damage to overhead-wire systems. Elsewhere east of the Rocky

Mountains the snowfall was mainly far less than is usually received in March.

In the western mountain districts the March snow was mainly near the normal, and on the whole the amounts stored in the high mountains at the end of the month gave promise of good supplies of water during the coming summer in practically every district where water for irrigation or power is a matter of great importance.

RELATIVE HUMIDITY

For the country as a whole the percentages of relative humidity were above normal, though there were sharp differences in the values at near-by points, notably in the Rocky Mountain region, where over the northern districts the percentages were frequently far below normal, while over the central portions they were as far above. Despite the great excess of precipitation over the middle and lower Mississippi Valley and near-by areas, the humidity percentages were only slightly above normal and occasionally even below.

The atmosphere was comparatively dry over the Florida Peninsula and portions of the Middle Atlantic States, coinciding with the general deficiency of precipitation over those regions.

SEVERE LOCAL STORMS, MARCH, 1927

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path [1]	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
North Carolina and southeastern Virginia.	1–2			2		Severe snow and wind.	Considerable property damage; interruption or delay in travel for several days; about one-half of peach crop killed or injured.	Official, U. S. Weather Bureau.
Atlantic seaboard, Maryland to New England.	2					Gale	4 lightships blown from moorings; a freighter blown ashore and a steamer grounded.	Do.
Clearwater, Fla	3			1		Wind	Small building wrecked	Do.
Orleans, Mass	4			5		Gale	Schooner Montclair wrecked	New York Times (N. Y.).
Macoupin County, Ill. (southwest).	5					Electrical	Farm home damaged	Official, U. S. Weather Bureau.
Colfax, La	6	10 a. m.				Moderate hail	Young vegetables injured	Do.
Iola, Kans. (near)	7	Midnight–2 a. m.			$2,000	Violent wind	Farm buildings damaged; hay and fodder scattered; trees prostrated.	Do.
Troy and Banks, Ala	9	4 a. m.			10,000	Wind	Buildings damaged	Do.
Luling, Tex	9	11:30 p. m.			23,000	do	Buildings and oil derricks badly damaged	Do.
Manta, Ga	9					do	Several small houses demolished	Do.
Holton (near) and Netawaka (near), Kans.	11	5:30 p. m.	33		7,000	Tornado	No towns in path; farm buildings damaged	Do.
Hiawatha (near), Kans	11	6 p. m.	1,760		3,000	Violent wind	Barns, outbuildings, and telephone poles blown down.	Do.
Wathena (near), Kans	11	8 p. m.	150		1,500	Tornado	Barns and small buildings damaged	Do.
Aurora (near), Ill	11	4:30–6 p.m.	16		150	Small tornado	Small structures and trees damaged	Do.
Memphis, Tenn	11					Severe wind and rain.	Streets flodded; trees and light poles blown down.	Do.
Indianapolis, Ind	12					Wind	Minor property damage reported	Do.
Alabama (northern) and Tennessee (western).	12–13					Heavy rains	Large areas flooded; railways suffer washouts; roads damaged; many families forced to leave homes.	Do.
Indiana	12–13					do	Extensive damage in some sections	Do.
Delight (near) to Collegeville (near), Ark.	17	7:30 p. m.	100	11		Tornado	About 3,000,000 feet of timber blown down; other property damaged; 28 persons injured.	Do.
DeLeon, Tex. (near)	17		3,520			Heavy hail	Roofs and auto tops pierced; poultry killed; cattle and other livestock badly burised; path 12 miles long.	Do.
Kremlin, Okla	18	6–7:30 p.m.	8 mi.		150	Moderate hail	Minor damage	Do.
Carroll County, Ark	18	7:30 – 8:30 p. m.	440	24	502,500	Tornado	Many houses demolished, others partially wrecked; barns and timber damaged; livestock killed; 108 persons injured.	Do.
Jerseyville, Ill. (3 miles north of).	18	11:55 p. m.	33		1,570	Small tornado	A farm house completely unroofed; path 500 feet long.	Do.
Bedford, Henderson, and Lewis Counties, Tenn.	18				20,000	Heavy hail	Many window panes broken; roofs damaged	Do.
Kay and Osage Counties, Okla.	18	10 p. m.			12,000	do	Damage chiefly confined to windows and roofs	Do.
Koskonong, Mo	18				200	Hail	Windows and roofs damaged; fruit injured	Do.
Oklahoma (north-central)	18					Tornadic wind	Character of damage not reported	Do.
Oklahoma	18					Destructive hail	Property damage in various parts of the State	Do.
Petersburg, Ill	18				500	Electrical	A church damaged	Do.
Bartlesville, Okla	19	Midnight–1 a. m.				Moderate hail	Glass in greenhouses and residences broken	Do.
Kansas (southwest)	19	A. m.	50 mi.		20,800	Glaze	Damage chiefly to telephone and telegraph lines.	Do.
Jefferson, Osage, and Shawnee Counties, Kans.	19	3 p. m.	5 mi.		10,000	Heavy hail	Roofs pierced; crops not far enough advanced to be hurt.	Do.
Missouri (northern half)	19					Thunderstorms, wind, and hail.	Considerable damage to roofs and windows	Do.
Illinois (northern)	19–20					Glaze	Telegraph and telephone companies sustain heavy losses; much injury to trees.	Do.
Iowa (eastern)	19–20					do	Trolley service interrupted; overhead wire systems impaired.	Do.
Bolivar, Mo	20				1,000	Thunderstorm and hail.	Houses swept from foundations	Do.
Corpus Christi, Tex	20					Severe thunderstorm.	No details reported	Do.
Fort Wayne, Ind., and vicinity.	20				2,000	Glaze	Overhead wires damaged	Do.
Michigan (central and southwestern).	20					do	do	Do.
Mississippi (southern)	20					Wind	Character of damage not reported; 2 persons injured.	Do.
Mobile, Ala	21	2 a. m.			250	Thundersquall	One building unroofed	Do.
Redding, Calif	31	5:30 p. m.				Thunderstorm, wind, and hail.	Character of damage not reported	Do.
San Saba, Tex. (vicinity of)	29	5:30 p. m.	300			Wind and hail	Poles broken; crops and fruit trees injured; weak buildings damaged; 4 persons injured.	Do.
San Luis Obispo and Santa Barbara Counties, Calif.	29					Thunderstorm and hail.	Windows broken; trees stripped of foliage	Do.
Cartersville, La	31	6 p. m.	800		1,000	Thundersquall	A store, 2 oil derricks, and timber blown down; 1 person injured; path 10 miles long.	Do.
Springfield, Ill., and vicinity.	31	11 p. m.				Wind	Minor damage reported	Do.
Rapid City, S. Dak	31					Heavy snow	Roofs of several buildings collapsed; traffic obstructed.	Do.

[1] Yards when not otherwise specified; mi. signifies miles.

STORMS AND WEATHER WARNINGS

WASHINGTON FORECAST DISTRICT

Storm warnings were issued in connection with five disturbances during the month. On the morning of the 1st a disturbance of very slight intensity was centered near the mouth of the Mississippi River and pressure was abnormally high over southern Canada and the greater part of the United States east of the Rocky Mountains. Two p. m. special observations indicated that the disturbance would advance to the Georgia coast and move rapidly northeastward with a marked increase in intensity. Accordingly, northeast storm warnings were ordered displayed at 4:30 p. m. from Beaufort, N. C., to Atlantic City, N. J., and at 10 p. m. northwest warnings were displayed from Jacksonville, Fla., to Savannah, Ga. The following morning the storm center was near Cape Hatteras, where the barometer reading was 29.22 inches, and at 9:30 a. m. northwest storm warnings were ordered north of Savannah to Morehead City, N. C., and northeast warnings north of Atlantic City to Boston, Mass. At 2 p. m. the northeast warnings were extended to Eastport, Me. This storm increased in area and intensity and became quite severe. Maximum wind velocities of 60 miles an hour or more were reported quite generally along the Atlantic coast from Cape Hatteras to Cape Cod, Hatteras reporting 70 miles per hour from the north, and Nantucket and Highland Light, Mass., 72 and 74 miles per hour, respectively, from the northeast. This was by far the most severe storm during March.

The morning of the 8th a disturbance of marked intensity was central over the upper St. Lawrence Valley with a trough extending southward to the North Carolina coast, and northeast storm warnings were displayed at 9:30 a. m. from Cape Hatteras to Boston. Several stations reported maximum velocities in excess of 40 miles per hour, and New York City reported 64 miles per hour from the northwest. The following morning a disturbance of moderate intensity that had developed over northern Mexico was centered over Georgia, moving east-northeastward, and northeast storm warnings were displayed at 11 a. m. from Beaufort, N. C., to the Virginia Capes. This disturbance did not increase in intensity as expected; consequently no winds of gale force occurred.

No further warnings were required until the 24th, when a disturbance of moderate but increasing intensity was advancing northeastward over the ocean between Bermuda and the southern New England coast. At 4:30 p. m. northeast storm warnings were displayed from Block Island, R. I., to Boston. The highest velocity reported on the coast was 52 miles per hour from the northeast at Nantucket. By the time this storm had reached Newfoundland the barometer had fallen to 28.88 inches near its center.

The last warnings of the month were displayed at 6 p. m. of the 26th from Cape Henry to Atlantic City in connection with a secondary disturbance that developed over Maryland and Virginia and advanced eastward over the ocean. It did not increase materially in intensity, however, and no strong winds occurred along the coast.

Small-craft warnings were displayed along the Mississippi, Alabama, and extreme northwest Florida coasts on the 1st and 12th and along portions of the Atlantic coast on the 9th, 23d, 24th, and 25th. A warning of strong northerly winds for the Panama Canal Zone was issued the evening of the 2d.

Few frost warnings were required during the first 20 days of the month and were confined to the South Atlantic and east Gulf States. The most important warnings of the month were those of the 2d and 3d. Killing frost and freezing temperature occurred from Mobile, Ala., eastward to Jacksonville, Fla., on the morning of the 3d, and light to heavy frost as far south as Miami the following morning.

On account of unseasonably warm weather between the 5th and 21st vegetation advanced quite rapidly and frost warnings were required as far north as Kentucky and southern Virginia by the latter date. Frequent warnings were issued during the last 10 days of the month, but no killing frosts were reported.—*C. L. Mitchell.*

CHICAGO FORECAST DISTRICT

Mild temperatures, with only slight interruptions to cooler weather, continued throughout the month in practically the entire forecast district. The excess in temperature was considerable from the Great Lakes westward, record-breaking maxima, for so early in the season, of 76° at Omaha and 68° at Minneapolis being reported on the 15th, and 71° at Chicago on the 16th; and the only deficiency was in the extreme southwest portion of the district.

The weather, otherwise, was not unusual, except for rather heavy precipitation in the lower Ohio, middle Mississippi and lower Missouri Valleys and adjoining sections, resulting in some flood conditions.

The low-pressure areas which crossed the forecast district, almost without exception, came from the far West, and in their passage the centers lay either in the middle or in the northerly portions of the district, with the troughs extending to the south.

Advisory messages were sent to open ports on Lake Michigan, on several occasions, in advance of storm conditions; and an especially strong warning was issued on the night of the 31st, when the weather map showed a marked storm development in the middle Missouri Valley. This storm moved directly eastward, and strong winds occurred within the next 24 to 36 hours over the greater portion of Lake Michigan.

No casualties were reported on the lake during the month and navigation increased over the southern half during the closing days, due to unusual freedom from ice following the protracted mild weather.

Special warnings were sent daily to certain interests, including shippers of apples from the North Pacific States, banana interests and shippers of ink in the Middle West.—*H. J. Cox.*

NEW ORLEANS FORECAST DISTRICT

Moderate weather prevailed over most of the district during March. Cold-wave warnings were issued on the night of the 18th for Oklahoma, northwestern Texas, and northwestern Arkansas, were repeated on the 19th, and were extended on that date over Arkansas, the interior of Texas, and northwestern Louisiana. On the morning of the 20th warnings were extended to the Texas coast. These warnings were verified over most of the territory covered and temperature fell decidedly throughout the district.

Frost or freeze warnings were issued for parts of the district on the 1st, 2d, 3d, 9th, 12th, 17th, 20th, 21st, 22d, and 24th; frost occurred generally in the areas covered, and no frost of any consequence occurred without warnings.

Storm warnings were displayed on parts of the Texas coast and small-craft warnings for the other portions on the 1st, 8th, 11th, and 19th, and small-craft warnings on the 4th, 7th, 10th, 25th, and 31st. Winds occurred which justified the warnings. No general storm occurred without warnings.

"Norther" warnings were issued for United States shipping interests at Tampico, Mexico, on the 1st and and 21st.—*I. M. Cline.*

DENVER FORECAST DISTRICT

Viewing the month as a whole, there were marked contrasts in weather conditions over the district. In Montana and northern Wyoming very mild and dry weather prevailed, with mean temperatures from 3° to 8° above normal; in Utah and Colorado, on the other hand, cold and stormy weather predominated, especially in northeastern Colorado, where it was the coldest March since 1909, and where more than double the normal amount of precipitation occurred. In New Mexico and Arizona more settled conditions prevailed, with temperature and precipitation both somewhat below normal. Many LOWS passed eastward along the Canadian border and a number of active disturbances crossed the central portion of the district. On the evening of the 18th, a LOW in the southwest and a HIGH on the northeastern Rocky Mountain slope both having increased in intensity, with a sharp fall in temperature over Wyoming and northern Colorado, warning of a moderate cold wave was issued for southern Colorado and repeated for southwestern Colorado on the morning of the 19th. These warnings were fully verified over the regions specified, and the cold wave extended southward over New Mexico. On the evening of the 31st, with a LOW moving rapidly eastward over Kansas, followed by a sharp temperature fall in southeastern Wyoming and with mild temperature in eastern Colorado, a moderate cold-wave warning was issued for eastern Colorado. This warning was verified in the extreme eastern part of the State. Warnings to the air-mail service of fresh to strong westerly winds were issued for Wyoming on the evening of the 6th, and for Wyoming and northeastern Colorado the evening of the 14th. Frost warnings were issued for southern New Mexico on the 29th and 31st; temperatures low enough for the formation of frost occurred in the latter instance.—*E. B. Gittings.*

SAN FRANCISCO FORECAST DISTRICT

Unlike February, when the area of high barometer normally found central off the California coast was feeble or wholly absent and cyclones moved onto the coast in low latitudes, the month of March passed with this area of high barometric pressure fully organized and persistent, and consequently the types of cyclones and anticyclones experienced over the far Western States were radically different from those of the preceding month. As is usual when the anticyclone off the California coast is fully organized, the rainfall over California is deficient, and March proved no exception to this rule. Another striking feature of the pressure distribution over the western North American Continent and the northeast Pacific Ocean was the persistent high barometric pressure with cold weather, the coldest of the winter, over the Bering Sea and the equal persistence of low barometric pressure over the Gulf of Alaska, whence cyclones on many days passed eastward or southeastward onto the continent, and thus frequently caused the formation of secondary cyclones over the intermountain region. As a result of the influences of these more or less persistent types of pressure distribution, the month passed without excessive rains in any part of the district, but with frequent occasions demanding the issue of warnings of frosts and freezing temperatures, except on the immediate coast. Storm warnings were rarely required and then only for the Washington and Oregon coasts and the inland waters of Washington.

After the 27th, the area of high barometric pressure off the California coast disappeared, and this disappearance was followed by general rains over California during the closing days of the month.

In addition to the general forecasts and warnings and the special forecasts for orchard heating, the district center issued regularly during the month flying-weather forecasts for the commercial airways of the district.—*E. H. Bowie.*

RIVERS AND FLOODS

By H. C. FRANKENFIELD

As the great flood in the Mississippi River and many of its tributaries continued at the end of the month, report thereon will be postponed until the end of the flood in the extreme lower river, which will probably be about the end of May.

Atlantic drainage.—Melting snows from high temperatures accompanied by moderate rains resulted in ordinary flood stages in the Connecticut River and in the Susquehanna River and tributaries in the State of New York about the middle of the month. The usual warnings were issued and the damages were small, virtually none in New England and about $5,000 in New York. Savings in New York through the warnings were about $10,000. There were also moderate floods in the rivers of the Carolinas between March 8 and 15 for which the usual warnings were issued. The damage was nominal.

East Gulf drainage.—There was a flood of substantial proportions in the Tombigbee River of Alabama and Mississippi, and in the Black Warrior River of Alabama, following the heavy rains of March 7, 8, and 13. Warnings were issued on March 9 and supplemented on March 13 and 14. At Demopolis, Ala., the crest in the Tombigbee River was 51.8 feet, 12.8 feet above the flood stage, on March 20, and the river was above the flood stage from March 10 to 29, inclusive. As movable property had been taken away preceding the high floods of January and February, the losses were very small, only about $4,900, while the reported value of property saved through the warnings was $24,925.

The rivers of the Pascagoula system were also in moderate flood about the middle of March. Warnings were issued and there was no damage of consequence. Pearl River, of Mississippi and Louisiana, was also in flood much of the month, especially at Jackson, Miss., but again there was no loss except as occasioned by suspension of business.

Great Lakes drainage.—Rains from March 18 to 21 caused moderate floods in the rivers of the Lake Erie drainage, but there was only some slight damage from overflow and seepage. Warnings were issued at the proper time.

Mississippi drainage—Ohio Basin.—The quite heavy rains during the third week of March resulted in floods throughout the Ohio River below Louisville, Ky., and in all its tributaries. They were not severe except in the Wabash system, in the Green River of Kentucky, and

in the Ohio below the mouth of the Tennessee River. At Evansville, Ind., there was a crest of 39.9 feet on March 25, and one of 52.8 feet at Cairo, Ill., on the same date. There was also a very moderate local flood in the Parkersburg, W. Va., district on March 23, but without damage. The lower river was still in flood at the close of the month, and further report thereon will be incorporated in the report to be made of the Mississippi flood.

The tributary floods in Pennsylvania and Ohio were not very alarming, although there was considerable flooding of lowlands in Ohio, and some low-lying streets in the city of Sidney, on the Miami River, were under water. The aggregate damage was not large. Over the Wabash system of Indiana the floods were more pronounced, and the lower Wabash and the extreme lower White River were still in flood at the close of the month. Losses aggregated $128,150, while the reported value of property saved by the warnings was $53,000.

The flood in the Cumberland River did not extend above Nashville, Tenn. It was well forecast, and the losses amounted to $218,000, of which $215,000 occurred at Eddyville, Ky. Money value of property saved by the warnings was $25,000.

The flood in the Tennessee River was quite marked from Florence, Ala., to the mouth of the river, mainly on account of a very heavy one-day rainfall of 3.25 to 4.15 inches on March 12–13. Warnings were issued promptly, and while more than 23,000 acres of land were overflowed, the reported losses were only $46,000. There was little remaining to lose after the flood of December-January. Savings by the warnings were given as $12,850.

Mississippi drainage except the Ohio.—The Mississippi above Cairo, Ill., except at St. Louis, Mo., was in moderate flood between March 22 and 26, and at the end of the month the advance of another rise had reached Hannibal, Mo. The Illinois River, except the extreme upper portion, continued generally in flood during the month, and there were also moderate floods in the Meramec and Osage Rivers of Missouri beginning on March 22 and continuing for a few days.

The moderate floods in the White and Black Rivers of Arkansas between March 18 and 30 were without special incident, as previous floods had caused all damage that could be done except at very high stages.

The Yazoo River of Mississippi remained in flood throughout the month.

The floods in the Ouachita and Atchafalaya Rivers will be taken up later in connection with the Mississippi flood.

There were floods of fair proportions during the early days of the month in the Sulphur River of Texas, and about the middle of the month in the Cypress River, also of Texas. Warnings were prompt and property valued at $7,500 was reported as saved thereby. Loss and damage amounted to $5,300.

West Gulf drainage.—The Sabine River of Louisiana and Texas was in moderate flood from March 14 to 17 and 24 to 30, from heavy rains on March 7, 8, 11, 20, and 21. Warnings were prompt and there were no losses of consequence.

A flood in the Trinity River of Texas, while more marked than the Sabine flood, was also unattended by material damage, and property valued at $8,000 was saved by the warnings.

NOTE.—The ice in the Wisconsin River at Wausau, Wis., went out on March 15, marking the earliest break-up since that of March 10, 1857.—*Press dispatch.*

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC DRAINAGE					
Connecticut:	Feet			Feet	
White River Junction, Vt.	15	19	20	15.0	Mar. 19-20
Hartford, Conn.	16	17	24	19.0	20
Susquehanna:					
Oneonta, N. Y.	12			14.9	15
Bainbridge, N. Y.	11	14	16	15.0	15
Binghamton, N. Y.	14	14	15	15.4	15
Unadilla; New Berlin, N. Y.	8	13	16	12.4	14
Chenango: Sherburne, N. Y.	8	13	16	9.1	14
		21	21	8.1	21
Tar: Greenville, N. C.	14	12	13	14.0	12-13
Neuse: Smithfield, N. C.	14	7	11	15.9	9-10
Cape Fear: Elizabethtown, N. C.	22	8	13	27.4	11
Peedee:					
Cheraw, S. C.	27	11	11	27.2	11
Mars Bluff, S. C.	17	[1]	2	17.5	Feb. 28 Mar. 1
		9	17	19.6	Mar. 14
Santee:					
Rimini, S. C.	12	[1]	19	13.9	Mar. 1
Ferguson, S. C.	12	[1]	21	13.3	2
Broad: Blairs, S. C.	15	10	10	15.2	10
EAST GULF DRAINAGE					
Tombigbee:					
Aberdeen, Miss.	33	14	17	37.0	15
Lock No. 4, Demopolis, Ala.	39	[1]	1	52.5	Feb. 22-23
		11	20	51.8	Mar. 20
Chickasawhay: Enterprise, Miss.	21	15	15	21.0	15
Pearl:					
Edinburg, Miss.	21	14	18	23.2	15
Jackson, Miss.	20	[1]	5	30.0	Feb. 23-24
		13	28	29.8	Mar. 21
Columbia, Miss.	18	[1]	6	21.2	Feb. 16
		23	27	18.3	Mar. 24-25
West Pearl: Pearl River, La.	13	[1]	[2]	16.4	Feb. 18
GREAT LAKES DRAINAGE					
Maumee:					
Fort Wayne, Ind.	15	21	25	17.6	Mar. 23
Napoleon, Ohio	10	22	23	11.6	23
Auglaize: Defiance, Ohio	10	21	23	11.6	22-23
Sandusky:					
Upper Sandusky, Ohio	13	20	22	15.0	21
Tiffin, Ohio	7	21	23	8.6	22
Fremont, Ohio	11	22	23	12.0	22
MISSISSIPPI DRAINAGE					
Ohio:					
Marietta, Ohio	33	23	24	34.3	23
Cloverport, Ky.	40	23	25	40.5	24
Evansville, Ind.	35	[1]	6	37.3	2
		20	[2]	39.9	25
Dam No. 48, Cypress, Ind.	35	1	5	35.9	3
		21	[2]	39.1	26-29
Mount Vernon, Ind.	35	1	5	36.0	3
		21	[2]		
Shawneetown, Ill.	35	2	6	35.7	4
		19	[2]		
Paducah, Ky.	43	20	27	44.6	24
Cairo, Ill.	45	17	[2]	52.8	25
Beaver: Beaver Falls, Pa.	11	21	21	11.2	21
Shenango: Sharon, Pa.	9	21	23	10.2	22
Muskingum:					
Zanesville, Ohio	25	22	24	26.7	22
McConnelsville, Ohio	22	21	25	25.8	23
Beverly, Ohio	25	23	23	25.2	23
Tuscarawas:					
Gnadenhutten, Ohio	9	20	25	15.2	22
Coshocton, Ohio	8	20	25	17.1	22
Walhonding: Walhonding, Ohio	8	20	23	14.2	21
Scioto:					
Larue, Ohio	11	20	22	15.0	21
Prospect, Ohio	10	20	24	15.0	22
Bellpoint, Ohio	9	20	23	11.5	21
Dublin, Ohio	8	21	21	8.5	21
Circleville, Ohio	10	20	24	16.2	22
Chillicothe, Ohio	16	21	24	22.1	23
Olentangy: Delaware, Ohio	9	20	22	14.9	21
Miami:					
Sidney, Ohio	12	20	22	14.2	21
Middletown, Ohio	15	22	22	15.1	22
Stillwater: Pleasant Hill, Ohio	13	20	21	15.0	20
Green:					
Lock No. 4, Woodbury, Ky.	33	14	15	33.5	15
		21	25	39.4	23
Lock No. 2, Rumsey, Ky.	34	13	[2]	40.6	27
Barren: Bowling Green, Ky.	20	21	23	22.4	22
Wabash:					
Bluffton, Ind.	11	20	24	14.0	22
Logansport, Ind.	15	22	22	15.0	22
Lafayette, Ind.	11	20	26	21.1	23
Covington, Ind.	16	20	27	24.6	24
Terre Haute, Ind.	16	21	29	20.7	25
Vincennes, Ind.	14	21	[2]	19.5	28
Mount Carmel, Ill.	16	19	[2]	24.3	28
Tippecanoe: Norway, Ind.	6	7	8	6.2	8
		14	15	6.2	14-15
		20	28	6.5	26

[1] Continued from last month. [2] Continued at end of month.

River and station	Flood stage	Above flood stages—dates From—	Above flood stages—dates To—	Crest Stage	Crest Date
	Feet			*Feet*	
White: Decker, Ind	18	21	[2]	25.8	Mar. 27
White, East Fork:					
Seymour, Ind	10	21	24	13.8	22
Williams, Ind	10	23	27	15.8	25
Shoals, Ind	20	23	28	26.6	26
White, West Fork:					
Anderson, Ind	12	20	22	17.5	21
Noblesville, Ind	14	20	22	18.1	21
Indianapolis, Ind	18	21	22	19.2	21
Elliston, Ind	19	19	27	28.1	23
Edwardsport, Ind	15	20	29	20.0	24
Cumberland:					
Nashville, Tenn	40	14	14	40.0	14
Clarksville, Tenn	46	13	17	51.1	15
Lock F, Eddyville, Ky	57	16	23	58.8	18
Tennessee:					
Widows Bar Dam, Ala	26	[1]	[3]	29.7	Feb. 27
		10	13	29.0	Mar. 12
Florence, Ala	18	12	15	23.9	13
Riverton, Ala	33	1	3	33.7	2
		11	19	44.3	14
Savannah, Tenn	40	14	18	43.0	15
Johnsonville, Tenn	31	14	22	36.3	16
Elk: Fayetteville, Tenn	14	9	9	15.4	9
Mississippi:					
Hannibal, Mo	13	31	[2]		
Louisiana, Mo	12	21	23	12.9	22
Grafton, Ill	18	21	25	19.7	22
Alton, Ill	21	21	25	22.9	22
Cape Girardeau, Mo	30	21	28	33.3	24
New Madrid, Mo	34	17	[2]	40.4	25–26
Cottonwood Point, Mo	34	20	[2]	37.6	27
Memphis, Tenn	35	18	[2]	41.4	30
Helena, Ark	44	20	[2]		
Arkansas City, Ark	48	[1]	1	51.8	Feb. 17–19
		21	[2]		
Greenville, Miss	42	24	[2]		
Vicksburg, Miss	45	[1]	[2]		
Natchez, Miss	46	[1]	[2]		
Angola, La	45	[1]	[2]		
Baton Rouge, La	35	[1]	[2]		
Donaldsonville, La	28	[1]	[2]		
New Orleans, La	17	[1]	[2]		
Spirit: Tomahawk, Wis	14	18	18	14.7	Mar. 18
Illinois:					
Morris, Ill	13	22	25	13.8	23–24
Peru, Ill	14	[1]	[2]	18.3	26
Henry, Ill	10	[1]	5	16.1	Feb. 9
		13	[2]	13.0	Mar. 26–27
Peoria, Ill	18	19	[2]	19.8	27
Havana, Ill	14	[1]	[2]	18.0	28–30
Beardstown, Ill	14	[1]	[2]	20.5	28–29
Pearl, Ill	12	[1]	[2]	18.0	22
Meramec:					
Pacific, Mo	11	20	23	15.8	22
Valley Park, Mo	14	20	23	17.0	23
Bourbeuse: Union, Mo	12	21	22	13.7	22
Missouri: St. Charles, Mo	25	21	21	25.3	21
Osage:					
Osceola, Mo	20	21	23	21.4	22
Warsaw, Mo	22	20	25	28.6	22
Tuscumbia, Mo	25	19	27	32.4	23
Arkansas: Yancopin, Ark	29	[1]	[2]		
Neosho: Oswego, Kans	17	20	22	20.1	21
Petit Jean: Danville, Ark	20	19	23	24.1	20
White:					
Batesville, Ark	23	18	18	23.8	18
Georgetown, Ark	22	22	31	22.9	26–27
Black:					
Poplar Bluff, Mo	14	19	22	14.8	19
Corning, Ark	11	14	[2]	13.6	23
Black Rock, Ark	14	18	[2]	19.9	21–22
Cache: Patterson, Ark	9	21	[2]	10.5	27
Yazoo: Yazoo City, Miss	25	[1]	[2]		
Tallahatchie: Swan Lake, Miss	25	[1]	7	31.1	Jan. 7–9
		10	[2]	31.8	Mar. 22
Sulphur:					
Ringo Crossing, Tex	20	1	5	26.3	2
		8	13	23.9	9
Finley, Tex	24	4	18	27.4	11
Cypress: Jefferson, Tex	18	14	16	19.2	15
Ouachita:					
Arkadelphia, Ark	18	8	8	18.6	8
Camden, Ark	30	10	17	35.0	12
Monroe, La	40	20	[2]		
Atchafalaya: Melville, La	37	[1]	[2]		
WEST GULF DRAINAGE					
Sabine: Logansport, La	25	14	18	25.8	16
		24	30	26.9	26
Trinity:					
Dallas, Tex	25	2	5	30.5	3
		7	11	31.6	9
Trinidad, Tex	28	5	18	37.0	13
Long Lake, Tex	40	17	19	40.4	18
Liberty, Tex	25	12	18	26.0	13–16
		22	30	26.8	27–28
Trinity, Elm Fork: Carrollton, Tex	7	2	2	7.8	2

[1] Continued from last month.
[2] Continued at end of month.
[3] Below flood stage at 8 a. m., Mar. 1.

MEAN LAKE LEVELS DURING MARCH, 1927

By UNITED STATES LAKE SURVEY

[Detroit, Mich., April 4, 1927]

The following data are reported in the Notice to Mariners of the above date:

Data	Lakes[1] Superior	Michigan and Huron	Erie	Ontario
Mean level during March, 1927:	*Feet*	*Feet*	*Feet*	*Feet*
Above mean sea level at New York	601.31	578.48	571.10	245.71
Above or below—				
Mean stage of February, 1927	−0.01	+0.23	+0.13	+0.40
Mean stage of March, 1926	+1.12	+0.94	+1.08	+1.57
Average stage for March, last 10 years	−0.07	−1.04	−0.28	+0.44
Highest recorded March stage	−1.01	−4.47	−2.75	−2.10
Lowest recorded March stage	+1.12	+0.94	+1.08	+1.57
Average departure (since 1860) of the March level from the February level	−0.10	+0.15	+0.18	+0.26

[1] Lake St. Clair's level: In March, 1927, 573.17 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, MARCH, 1927

By J. B. KINCER

General summary.—Precipitation was rather frequent during the first decade over the East and Southeast, attending the passage of several storm areas, but following these much colder weather overspread these sections, with freezing temperatures extending to the east Gulf coast. Temperature changes were not marked in the western part and precipitation was largely of a local character. Widespread rain or snow occurred in the Southwest during the second decade, with general rains throughout the interior. It was rather warm for the season in the East about the 18th, with widely scattered stations reporting the highest temperatures of record for so early in the spring. At the same time it was considerably cooler over western districts, with a marked fall in temperature over the Southwest on the 20th. A reaction to cooler set in over eastern sections during the last week, and in western States the tendency was still to rather low readings, although conditions were more seasonable. Precipitation was rather frequent during the latter part of the month over the central valleys and the lake region, and during the last week general rain or snow occurred over northern areas east of the upper Mississippi Valley.

The frost and freezing temperatures that overspread the Southeastern States early in the month, while not unusual for the season, caused considerable damage to early fruit bloom, and some harm resulted to tender vegetation. The frequent rainfall and cold weather made conditions rather unfavorable for field work in much of the South, and plowing and planting were not very active. Some cotton was planted in the southwestern part of the belt and a little corn was put in as far north as southeastern Oklahoma, but in much of the interior valleys the soil continued mostly too wet for field operations. Fruits continued their unseasonable advance, with the earlier varieties blooming as far north as southern Missouri and the lower Ohio Valley.

Much interruption to field work was reported during the second decade, although conditions became more favorable toward the close, with preparations for planting in the Cotton Belt advancing fairly well, but in portions of the Northwest it remained too wet. Except

where the soil continued too wet from previous heavy rains, preparations for spring work made good progress in most areas during the last decade, and seasonal operations were well advanced in the Atlantic Coast States, the South, and the Great Plains, with some potatoes put in as far north as Long Island and considerable oats seeded northward to southern Nebraska.

Small grains.—In the western Wheat Belt rain and melting snow furnished abundant moisture during the first part of the month and the crop made satisfactory progress generally, except in some west-central Plains sections. Some late-sown grain was in poor condition locally in the Ohio Valley, but rains and snows during the second week were favorable over the Great Plains region, while cereal crops made good advance in the South. Winter grains made material growth during the last decade and soil conditions were very satisfactory, due to abundant precipitation. In parts of the Ohio Valley, however, the soil on lowlands had been too wet and there was some local complaint of yellowing. Oat seeding made slow advance in the central valleys, due to wet soil, but considerable oats had been seeded to southern Nebraska at the close of the month.

Ranges, pastures, and livestock.—Pastures made good progress in the South during the month, and at its close grass was greening to the central portions of the country. Livestock continued to range freely over the northern Great Plains, with a consequent saving of feed. Precipitation over western grazing districts was very beneficial for the range, but caused some suffering of livestock during the last half. The weather was mostly favorable for lambing the latter part of the month, but previous conditions had caused some suffering.

Miscellaneous crops.—The frost that overspread the Southeast early in the month caused considerable damage to truck in Georgia and slighter injury elsewhere; protective measures saved a large acreage of truck in Florida. Potato planting advanced fairly well during the month and at the close was beginning on Long Island.

Although considerable injury to fruit was first reported, the harm, in general, was rather less than at first indicated. Fruit continued to advance considerably ahead of an average season, with early varieties blooming to the lower Ohio Valley, but the cooler weather the latter part of the month was favorable in checking too rapid progress.

WEATHER ON THE ATLANTIC AND PACIFIC OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

March was an unusually stormy month over the greater part of the North Atlantic. Over the steamer lanes the excess of days with heavy weather was not confined to any particular region, but the number of days with gales was above the normal along nearly the entire route from New York to the British Isles, although the weather over the eastern part of the southern lane was somewhat less turbulent. Many of the disturbances were very severe, and winds of force 11 and 12 were not uncommon, as shown by storm reports in the table.

Fog was unusually prevalent along the American coast between Hatteras and Nova Scotia, where it was reported on from 8 to 12 days. The number of days with fog over the Grand Banks was considerably below the normal; it was observed on 3 days in the Gulf of Mexico, on 5 days in the square between the fortieth and forty-fifth parallels and the twentieth and twenty-fifth meridians, and on from 1 to 3 days in the vicinity of the British Isles, while the greater part of the steamer lanes was practically clear.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian), North Atlantic Ocean, March, 1927*

Stations	Average pressure	Departure [1]	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	[2] 29.42	([3])	29.93	9th	28.87	22d.
Belle Isle, Newfoundland	29.83	+0.03	30.30	25th	29.20	16th.
Halifax	30.05	+0.15	30.50	11th	29.32	9th.
Nantucket	30.08	+0.08	30.52	12th	29.56	8th.
Hatteras	30.13	+0.10	30.42	5th	29.22	2d.
Key West	30.10	+0.07	30.30	5th	29.94	22d.[4]
New Orleans	30.12	+0.09	30.42	3d	29.92	9th.
Swan Island	29.94	−0.04	30.08	5th	29.88	13th.[4]
Turks Island	30.12	+0.10	30.22	5th [4]	30.00	3d.
Bermuda	30.15	+0.12	30.42	13th [4]	29.56	3d.
Horta, Azores	30.21	+0.09	30.64	4th	29.80	19th.
Lerwick, Shetland Islands	29.58	−0.12	30.34	13th	29.00	7th.
Valencia, Ireland	29.65	−0.25	30.30	12th	28.59	25th.
London	29.96	−0.22	30.36	15th	28.87	25th.

[1] From normals shown on H. O. Pilot Chart based on observations at Greenwich mean noon, or 7 a. m., seventy-fifth meridian.
[2] Mean of 22 observations; 9 days missing.
[3] No normal established.
[4] And on other dates.

On the 1st there was a shallow depression in the Gulf of Mexico that afterward developed into a severe disturbance as it moved northeastward along the American coast, as shown by Charts VIII to XI, that cover the period from the 2d to 5th, inclusive. These charts also give an idea of the disturbance over the eastern section of the ocean that was especially well developed on the 3d and 4th.

From the 6th to 14th there were few well-defined disturbances of any great extent or intensity, although during this period a number of vessels in various parts of the ocean reported gales, while moderate weather prevailed over large areas.

On the 15th an area of low pressure was over Newfoundland, and a second LOW central near 50° N., 25° W. On the 16th the center of the western LOW was near St. Johns, Newfoundland, and the eastern near 46° N., 18° W.; they had both increased in intensity, and westerly winds of force 9 to 11 prevailed over the region between the fortieth and sixtieth meridians, north of the fortieth parallel, while moderate to strong gales were also encountered east of the twentieth meridian. By the 17th the western LOW was central near 47° N., 37° W., and the storm area extended from the thirty-fifth to the fiftieth parallel and the thirtieth to the fiftieth meridian. The eastern LOW of the 16th had apparently moved eastward, gradually filling in, as on the 17th moderate weather prevailed east of the thirtieth meridian.

On the 18th the conditions were much the same as on the previous day although the storm area was somewhat less in extent.

On the 20th a depression of limited area was central near 44° N., and 40° W.; this moved slowly eastward, and on the 27th was off the north coast of Scotland. During this period gales were prevalent over the middle and eastern sections of the steamer lanes, the storm area varying from day to day in extent and intensity.

On the 24th a slight depression was in the vicinity of Bermuda; it moved northward, increasing in intensity, and on the 25th, when central near 37° N., 68° W.,

strong gales swept the region between the thirty-fifth and forty-fifth parallels, west of the sixtieth meridian.

On the 26th and 27th the storm area extended as far east as the forty-fifth meridian, the disturbance reaching its greatest intensity on the 26th.

On the 28th and 29th the central portion of the steamer lanes was covered by a LOW, and westerly winds of force 7 to 10 occurred over the southerly quadrants.

A slight depression, that on the 29th was central near 37° N., 57° W., moved eastward, and on the 31st was near 40° N., 50° W. During this period winds of force 7 to 9 prevailed near the center of the LOW.

NOTE.—Lieut. E. H. Kincaid, United States Navy, while on board the U. S. S. *Kittery*, near 30° N., 70° W., on March 28, observed a heavy hail squall.

OCEAN GALES AND STORMS MARCH, 1927

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				Inches					
Jomar, Am. S. S.	Pasajes, Spain	Pensacola	25 51 N.	83 04 W.	Mar. 1	10 p., 1	Mar. 3	29.94	WSW	WSW., 7	N	—, 8	WSW.-WNW.
Steel Navigator, Am. S. S.	New York	Colon	36 07 N.	74 07 W.	2	—, 2	3	28.92	NE	N., 12	NW	N., 12	E.-N.
Gallier, Belg. S. S.	Antwerp	New York	40 37 N.	70 05 W.	2	11 p., 2	3	29.43	NE	N., 11	N	NNE., 11	NE.-NNW.
Sac City, Am. S. S.	do	do	38 10 N.	39 45 W.	1	Noon, 2	2	29.64	S	SW., 12	NW	SW., 12	SW.-WNW.
Conte Rosso, Ital. S. S.	New York	Naples	39 50 N.	58 45 W.	3	4 a., 3	4	29.03	ENE	—, SSE	SSW	S., 11	Steady.
Iroquois, Br. S. S.	do	London	45 20 N.	32 00 W.	3	11 p., 3	4	28.91		N., 10		N., 11	N.-NNW.
Eglantine, Am. S. S.	Avonmouth	Boca Grande, Fla.	49 01 N.	11 25 W.	3	3 p., 3	5	29.46	SW	SW., 8	NNW	—, 11	SW.-WSW.
Aral, Br. S. S.	River Tyne	New Orleans	49 48 N.	7 50 W.	2	4 a., 5	9	29.23	SSW	NW., —	NNW	WNW., 10	WSW.-NW.
Innoko, Am. S. S.	Rotterdam	New York	44 18 N.	50 03 W.	9	11 p., 9	10	29.57	SSE	SSE., 9	W	SSE., 9	Steady.
Elzasier, Belg. S. S.	Antwerp	do	49 28 N.	13 30 W.	9	2 p., 9	10	29.97	NNW	NNW., —	NNW	NNW., 10	
Davisian, Br. S. S.	Liverpool	Boston	46 30 N.	39 02 W.	12	4 p., 12	13	30.02	WNW	WNW., 9	NW	NW., 9	WNW.-NW.
Bolivian, Br. S. S.	do	New Orleans	45 10 N.	22 00 W.	15	Mid't, 15	16	28.78	N	NW., 7	NW	NW., 12	N.-NW.
City of Weatherford, Am. S. S.	Rotterdam	do	45 40 N.	15 00 W.	15	6 a., 16	16	29.06	SSE	SW., 10	WNW	—, 10	SSE.-WSW.
Elzasier, Belg. S. S.	Antwerp	New York	44 47 N.	42 25 W.	15	8 a., 17	18	28.97	SSW	W., —	WNW	WSW., 12	
West Arrow, Am. S. S.	do	Boston	43 32 N.	41 46 W.	19	1 p., 20	21	29.10	WSW	NW., 9	NW	NW., 11	SW.-NW.
Saco, Am. S. S.	Manchester	Mobile	49 10 N.	16 23 W.	20	3 p., 20	24	29.25	SW	WSW., 9	W	W., 10	S.-WSW.
Asuncion de Larrinaga, Br. S. S.	Liverpool	Habana	47 58 N.	23 16 W.	18	3 a., 21	25	29.06	S	WSW., 7	NW	NW., 10	W.-SW.
Mijdrecht, Du. S. S.	Vigo	New York	45 20 N.	35 55 W.	23	8 a., 23	24	29.53	SW	SW., 8	NNW	NW., 10	SW.-W.
Arundo, Du. S. S.	Rotterdam	Gulfport	48 08 N.	10 48 W.	22	9 a., 23	27	29.18	SW	WSW., —	NW	W., 10	
Colonian, Br. S. S.	Halifax	Fastnet	49 27 N.	33 02 W.	23	8 p., 24	25	29.43	WNW	WNW., 10	WNW	NNW., 10	Steady.
Ossa, Am. S. S.	Casablanca	New York	37 14 N.	68 53 W.	25	—, 25	26	29.08	N	N., 12		N., 12	N.-NNW.
Savoia, Ital. S. S.	Gibraltar	do	38 30 N.	65 38 W.	25	5 p., 25	26	28.92	N	N., 11	N	N., 12	NNW.-N.
München, Ger. S. S.	Cobh	do	51 06 N.	15 51 W.	24	4 a., 25	28	28.68	SSW	W., 10	NW	W., 11	W.-WNW.
E. M. Clark, Am. S. S.	Halifax	Canal Zone	36 33 N.	68 02 W.	24	7 a., 25	26	29.17	E	SSE., 7	NW	W., 12	
Conte Rosso, Ital. S. S.	Naples	New York	41 24 N.	51 45 W.	26	8 p., 26	27	29.33	S	S., 10	NNW	S., 10	Steady.
Albert Ballin, Ger. S. S.	Southampton	do	48 13 N.	23 00 W.	29	Noon, 29	30	29.80	WSW	WSW., 9	W	WSW., 9	WSW.-W.
Chincha, Am. S. S.	Bordeaux	do	37 00 N.	61 00 W.	30	4 a., 30	30	29.93	SW	SW., 6	NNE	NNE., 10	SW.-W.-NNE
Nieuw Amsterdam, Du. S. S.	Rotterdam	do	49 45 N.	7 48 W.	31	7 p., 31	Apr. 1	29.61	SW	W., 10	NNW	NW., 10	
NORTH PACIFIC OCEAN													
Emp. of Russia, Br. S. S.	Yokohama	Victoria	46 26 N.	168 27 E.	1	4 a., 1	Mar. 1	28.74	SE	SE., 4	S	SSW., 9	SE.-S.-SW.
Do	do	do	50 27 N.	140 44 W.	3	4 p., 4	5	29.25	SW	SW., 6	W	SW., 9	Steady.
Java Arrow, Am. S. S.	San Francisco	Balboa	14 30 N.	96 00 W.	2	4 p., 2	3	29.94	NE	NE., 7	NE	NE., 9	Steady.
Shidzuoka Maru, Jap. S. S.	Yokohama	Victoria	49 00 N.	160 00 W.	2	4 a., 4	5	28.55	E	SW., 5	WSW	E., 8	
Stanley, Am. S. S.	Honolulu	Kobe	32 08 N.	141 42 E.	4	7 p., 4	5	29.50	E	E., 7	NE	E., 10	Steady.
Unkai Maru, Jap. S. S.	Muroran	Portland	49 01 N.	146 47 W.	4	4 p., 4	6	29.09	S	SSW., 10	WSW	SSW., 10	S.-SSW.
Memphis City, Am. S. S.	San Pedro	Yokohama	32 44 N.	147 00 E.	5	2 p., 5	5	29.17	S	SSW., —	NW	NNW., 12	SSW.-NNW.
Oak Park, Am. S. S.	Honolulu	Kobe	30 34 N.	150 10 E.	5	4 p., 5	6	29.47	E	WSW., 8	NW	W., 9	SW.-W.
West Hixton, Am. S. S.	Shanghai	San Francisco	45 36 N.	173 41 E.	6	3 p., 7	7	28.92	E	NNE., 8	NW	NE., 9	ENE.-NNE.
Do	do	do	46 50 N.	172 50 W.	9	2 p., 9	11	29.36	ESE	NNE., 8	WNW	NNW., 9	
Silvercedar, Br. S. S.	San Pedro	Yokohama	33 45 N.	142 15 E.	9	4 a., 11	11	29.25	S	SW., 11	NW	SW., 11	WSW.-W.
Harold Dollar, Br. S. S.	Karatsu	San Francisco	46 45 N.	144 30 W.	10	10 a., 10	11	29.27	S	SW., 10	WSW	SW., 10	Steady.
Stockton, Am. S. S.	Honolulu	San Pedro	29 30 N.	141 50 E.	11	9 a., 11	11	29.85	W	WNW., 8	NNW	WNW., 8	W.-WNW.
Do	do	do	33 50 N.	152 34 E.	14	11 a., 14	14	29.63	WSW	N., 10	N	N., 10	WSW.-N.
Protesilaus, Br. S. S.	Yokohama	Victoria	37 30 N.	145 50 E.	11	3 p., 11	14	29.22	W	WNW., 8	NW	NW., 9	W.-NW.
Akagisan Maru, Jap. S. S.	do	San Francisco	44 50 N.	167 15 W.	12	8 a., 13	13	29.51	SSE	S., 9	SE	S., 9	S.-SSW.
Grace Dollar, Am. S. S.	Manila	do	41 37 N.	146 45 E.	12	Mid't, 12	13	29.27	WNW	NW., 7	NW	NW., 10	Steady.
Chickasaw City, Am. S. S.	Yokohama	Shanghai	43 40 N.	169 10 W.	16	—, 17	17	29.75	N	N., 7	N	N., 8	Steady.
Hakutatsu Maru, Jap. S. S.	Muroran	Portland	48 50 N.	150 37 W.	18	6 a., 18	18	29.46	SSW	SSW., 7	W	SW., 8	
Do	do	do	48 06 N.	138 50 W.	20	4 a., 20	20	29.87	SW	SW., 7	W	SW., 9	
Lubrico, Am. S. S.	Baltimore	San Francisco	32 48 N.	119 40 W.	18	—, 18	19	29.94	NW	NW., —	NNW	NW., 9	NW.-NNW.
China Arrow, Am. S. S.	Surabaya	do	43 10 N.	158 45 E.	20	6 p., 21	23	28.75	NE	SW., 5	W	WNW., 12	SSW.-W.
Las Vegas, Am. S. S.	Otaru	do	42 25 N.	172 20 E.	21	—, 22	22	29.54	SE	S., —	W	—, 9	S.-SW.
City of Vancouver, Can. S. S.	Yokohama	Victoria	42 45 N.	158 56 E.	21	6 p., 21	22	28.61	SSE	WSW., 6	W	W., 11	S.-WNW.
Pres. Lincoln, Am. S. S.	San Francisco	Manila	47 30 N.	170 00 E.	21	5 a., 22	23	28.91	SSE	S., 10	SW	S., 11	SE.-SW.
Robert Dollar, Can. S. S.	Karatsu	San Francisco	49 05 N.	171 44 E.	25	8 a., 26	27	28.95	ENE	WNW., 8	NW	W., 10	Variable.
West Calera, Am. S. S.	Hongkong	do	37 13 N.	147 00 E.	26	4 a., 27	27	29.16	SE	NW., 12	NW	NW., 12	NE.-NW.
Yuri Maru, Jap. S. S.	Miike	Portland	40 46 N.	152 22 E.	26	—, 27	27	28.80		S., 8		S., 8	S.-SW.
Makena, Am. S. S.	Ahukini	San Francisco	35 48 N.	129 45 W.	27	4 a., 28	29	29.90	NW	N., 9	NE	N., 9	NW.-N.
Tahchee, Br. S. S.	Shanghai	San Pedro	40 00 N.	167 30 W.	29	8 a., 29	29	29.89	NNE	NNE., 7	NNE	NNE., 8	Steady.
Waiotapu, Br. S. S.	Newcastle	Vancouver	33 34 N.	148 30 W.	28	8 p., 28	30	29.56	SE	SE., 9	ESE	SE., 9	

NORTH PACIFIC OCEAN

By WILLIS E. HURD

The Aleutian LOW, having in February dominated the weather of the North Pacific far down into middle latitudes, receded northward at the close of that month, and practically throughout March hung over the higher latitudes, being central most of the time over the northwestern part of the Gulf of Alaska. At the same time, the North Pacific HIGH largely covered middle latitudes, having regained the position it lost in February. As a result of these pronounced changes in pressure distribution gales moderated considerably in force and frequency over the entire upper reaches of the ocean east of the one hundred and eightieth meridian, where storminess was much less than during any previous month since November.

The pressure at Dutch Harbor underwent a remarkable change. Its average reading for February was 29.19 inches, which is the lowest in recent years. In March it rose to 29.85 inches, which is the highest reading for the month during a similar period. At St. Paul the pressure in March was more than one-quarter inch above the normal, while at Kodiak, the center of lowest pressure this month, it was nearly as much below, thus establishing a remarkable pressure gradient over Bering Sea.

The following table illustrates the pressure conditions at various stations in west longitudes:

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean, March, 1927*

Station	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Dutch Harbor [1]	29.85	+0.11	30.34	16th [5]	29.38	4th. [5]
St. Paul [1]	30.03	+0.28	30.52	16th	29.38	22d.
Kodiak [1]	29.52	−0.23	30.36	30th	28.86	11th.
Midway Island [1 4]	30.15	+0.07	30.28	10th [5]	29.90	8th.
Honolulu [2]	30.04	0.00	30.19	1st	29.79	28th.
Juneau [2]	29.75	−0.19	30.26	22d	28.94	7th.
Tatoosh Island [2 3]	30.06	+0.08	30.52	22d	29.48	30th.
San Francisco [2 3]	30.08	+0.03	30.31	15th	29.78	9th.
San Diego [2 3]	30.04	+0.02	30.20	12th	29.76	10th.

[1] P. m. observations only.
[2] A. m. and p. m. observations.
[3] Corrected to 24-hour mean.
[4] 30 days.
[5] And on other dates.

The atmospheric pressure in the Far East was much like that of February, except that the continental HIGH showed distinct evidences of breaking up with the approach of spring, in that an increasing number of cyclones and depressions had origin over eastern China or off the immediate coast. No less than five storms, three of which may be characterized as of major importance, moved out of this area.

The storm of the 2d to 6th formed east of Taiwan, moved northeastward, and disappeared a few hundred miles east of central Japan. On the 4th and 5th it caused gales over a considerable stretch of sea southeast of Honshu, culminating in a northwest hurricane on the 5th, as reported by the American steamer *Memphis City*, which rode out the full force of the storm during the afternoon, minimum pressure 29.17 inches. This storm will be classed undoubtedly as a typhoon.

The four succeeding storms were of continental origin, having nearly the same source over eastern or central China. That of the 7th to 14th moved rapidly seaward and crossed the Japan Sea during the 8th and 9th, causing moderate to strong gales along most of the eastern and western coasts of the archipelago. From the 10th to 12th it moved northeastward across the Okhotsk Sea to Kamchatka, crossed the intervening space to the western Aleutians during the 13th, and joined with the Aleutian LOW over the Gulf of Alaska on the following day. A secondary to this cyclone caused violent gales southeast of Honshu early on the 11th.

A disturbance of briefer existence left China on the 11th and disappeared at sea in middle latitudes on the 14th, after causing some rough weather over the Eastern Sea and the south coast waters of Japan.

The storm that cleared the continent on the 18th moved along the southern coast of Japan on the two following days. On the 20th it rapidly gained in energy, and on the 21st caused hurricane winds over a considerable area central near 43° N., 159° E. On the 22d, continuing violent, it crossed to the western Aleutians, with whole gales to storm winds blowing along its southern quadrants. It crossed Bering Sea on the 23d, and died out over the northeastern part of the Gulf of Alaska on the 24th.

The last Chinese storm of the month left the continent on the 22d, and became violent east of Japan on the 27th, on which date the *West Calera* encountered a northwest hurricane in 37° 13′ N., 147° E. Thereafter the storm diminished and disappeared, apparently in the Aleutian area.

No gales exceeding force 10 were reported from the sea in west longitudes. The moderate to strong gales that did occur over this vast region were mostly encountered along the upper steamship routes. At points on the Washington coast there were heavy gales early in the month, the Weather Bureau station at Tatoosh Island reporting a 64-mile wind from the southwest on the 1st, and a 65-mile wind from the south on the 5th, while the station at North Head had a 63-mile wind from the south on the 7th. At Juneau, Alaska, the maximum wind velocity was at the rate of only 32 miles an hour, yet the average hourly velocity, 9.7 miles, showed the highest wind movement on record here for March.

The weather in southern latitudes was quiet for the most part. A norther of force 9 occurred in the Gulf of Tehuantepec on the 3d, and strong winds to moderate gales were experienced by the British steamer *Wairuna* from the 6th to the 9th between the Equator and the Hawaiian Islands. These were easterly as a rule and were unaccompanied by pressure changes.

At Honolulu the maximum wind velocity was 35 miles from the northwest on the 22d. The average hourly velocity was 9.8 miles, and the prevailing direction from the east. The total rainfall was 6.67 inches, which is 0.47 inch above the normal. Of this amount 3.94 inches fell within 24 hours on the 22d and 23d. The first hail ever recorded by the Weather Bureau at Honolulu since its establishment in 1904 fell here during a thunderstorm on the 23d.

Fog diminished along the American coast since February, but increased somewhat over the open ocean to the westward. The principal fog area lay between 35° and 50° N., 130° and 170° W., where it was observed scatteringly on 13 days. There were three days with fog northwest of Midway Island, and a few days with it east of Japan. On the 21st the American steamer *China Arrow* had dense fog from 8.30 a. m. until 2.30 p. m., following upon heavy rains near 43° N., 157° E. When the fog cleared it was followed by more rain and by increasing winds which terminated in hurricane velocities late in the evening. Fog occurred south of Hongkong on the 7th to 9th, and was reported up the coast on the

12th. March is the month of most frequent fogs in lower Chinese waters.

On the 24th the American steamer *West Holbrook*, in 42° 15′ N., 144° 56′ E., reported "ice floes in great quantities, but of small size. Temperature of sea and air, 30°."

A MADAGASCAR CYCLONE

The Weather Bureau has no reports as yet concerning the tropical cyclone in the Indian Ocean which struck Madagascar on March 1, other than those furnished to the press, which state that a terrific storm devastated the port of Tamatave on that day. The harbor was wrecked and all steam and sailing vessels within it were destroyed, while several hundred lives were reported lost. A tidal wave added to the destruction within the city, and caused great losses along many miles of the coast. Wireless messages from vessels told of the intensity of the storm at sea. The island of Reunion was later reported as swept by the cyclone.—*W. E. H.*

CLIMATOLOGICAL TABLES[1]

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, March, 1927

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	57.0	+0.9	Ozark	89	18	Valley Head	19	[2] 3	4.89	−0.86	Riverton	9.75	Alaga	0.97
Arizona	52.3	−0.7	Quartzsite	98	25	Fort Valley	−1	12	1.15	−0.01	Natural Bridge	3.31	Bowie	0.07
Arkansas	53.5	+0.8	3 stations	87	[2] 19	Dutton	5	3	7.24	+2.50	Yancopin	15.70	Magnolia	2.65
California	50.4	−1.2	Amos	100	27	Helm Creek	−13	10	2.62	−1.18	Crescent City	10.25	Greenland Ranch	0.00
Colorado	32.6	−1.8	2 stations	78	[2] 8	Hermit	−36	20	1.82	+0.53	La Veta Pass	6.42	Blanca	0.10
Florida	65.7	0.0	Brooksville	91	[2] 16	Vernon	26	[2] 3	2.38	−0.52	Bluff Springs	5.16	Miami Beach	0.54
Georgia	58.2	+1.5	Alapaha	91	18	Blue Ridge	14	3	3.15	−1.64	Clayton	6.32	Bainbridge	1.01
Idaho	35.9	+0.1	Orofino	79	30	Stanley	−19	16	1.22	−0.29	Roland	4.07	Geneva	0.20
Illinois	44.4	+3.8	Harrisburg	78	19	Mount Carroll	10	3	4.60	+1.39	Cairo	8.07	Rockford	1.55
Indiana	44.0	+3.3	Marengo	78	19	2 stations	12	[2] 2	4.69	+0.83	Rome	9.96	Notre Dame	2.02
Iowa	39.6	+4.9	Tipton	75	16	Inwood	0	21	1.92	+0.17	Fairfield	3.64	West Bend	0.62
Kansas	43.2	−0.4	3 stations	80	15	2 stations	−7	1	2.84	+1.44	Pleasanton	10.09	Ulysses	0.51
Kentucky	48.4	+2.0	Williamsburg	82	20	3 stations	10	3	6.04	+1.20	Murray	12.71	Hazard	2.36
Louisiana	61.1	+0.4	3 stations	87	[2] 19	2 stations	26	[2] 3	7.39	+2.72	Monroe	12.40	Burrwood	3.16
Maryland-Delaware	45.4	+2.8	Hancock, Md	84	17	2 stations	10	4	1.75	−1.91	Grantsville, Md	3.19	Ferry Landing, Md.	1.21
Michigan	35.7	+6.0	3 stations	73	[2] 16	2 stations	−22	[2] 1	2.00	−0.18	Benzonia	3.62	Iron River (near)	0.21
Minnesota	31.9	+5.8	Waseca	80	[2] 13	Itasca State Park	−22	2	1.52	+0.36	New Ulm	3.82	Hallock	0.21
Mississippi	57.3	+0.6	3 stations	87	19	Monticello	21	4	8.27	+2.77	Austin	12.89	Shubuta	3.79
Missouri	45.9	+2.1	Marshall	80	16	Hollister	0	3	5.87	+2.87	Bolivar	11.24	Downing	1.69
Montana	32.9	+2.7	Foster	75	14	Hebgen Dam	−18	20	0.61	−0.30	Adel	2.49	Livingston	T.
Nebraska	36.8	+1.2	Syracuse	77	15	Madrid	−16	1	2.57	+1.47	Albion	4.97	Fort Robinson	0.90
Nevada	41.7	−0.1	Las Vegas	88	25	Owyhee	−1	19	0.84	+0.03	Tuscarora	2.12	Mina	T.
New England	35.6	+3.4	Waterbury, Conn	75	17	Pittsburgh (a), N.H.	−19	2	1.49	−1.76	Somerset, Vt	2.75	Milo, Me	0.33
New Jersey	41.9	+3.3	2 stations	81	18	Layton	9	2	1.46	−2.43	Indian Mills	2.73	New Brunswick	0.78
New Mexico	43.4	+0.1	Jal	88	27	Elizabethtown	−21	21	0.71	−0.14	Cloverdale	6.42	8 stations	0.00
New York	36.2	+4.2	Dansville	80	17	North Lake	−18	2	1.98	−1.08	High Market	3.54	Chazy	0.41
North Carolina	51.4	+1.1	3 stations	88	[2] 17	Rockingham	7	5	3.41	−0.97	Mount Mitchell	8.09	Terra Ceia	1.03
North Dakota	30.4	+7.8	Carson	77	14	McKinney	−10	2	0.74	−0.09	Fullerton	2.26	Pembina	0.00
Ohio	42.7	+3.1	Portsmouth	81	16	Norwalk	9	4	3.83	+0.33	Miamisburg	5.82	Put in Bay	1.87
Oklahoma	50.7	−1.4	2 stations	86	[2] 7	2 stations	−1	1	2.62	+0.53	Hugo	7.26	Elk City	T.
Oregon	41.7	−0.5	Pilot Rock	75	30	Lake	7	5	2.77	−0.36	Willow Creek	10.07	Riley	0.26
Pennsylvania	42.0	+4.5	Hyndman	82	17	West Bingham	−6	2	2.61	−0.93	Creekside	5.43	Doylestown	0.69
South Carolina	55.2	+0.4	Camden	89	20	Spartanburg	16	3	3.79	−0.11	Caesars Head	6.15	Yemassee	2.18
South Dakota	34.9	+4.0	Hopewell	77	14	Menno	−12	21	1.26	+0.21	Canton	3.18	2 stations	T.
Tennessee	51.1	+1.7	Etowah	86	10	Rugby	3	3	7.49	+2.18	Brownsville	13.66	Bristol	2.84
Texas	58.7	0.0	Falfurrias	104	31	Dalhart	−1	[2] 1	2.33	+0.27	Groveton	9.70	3 stations	0.00
Utah	38.3	+0.4	Hanksville	82	27	Woodruff	−14	10	1.73	+0.25	Silver Lake	4.47	Fort Duchesne	T.
Virginia	48.2	+2.2	Woodstock	89	18	Burkes Garden	0	4	1.86	−1.98	Emory	4.17	Dale Enterprise	0.65
Washington	40.4	−0.1	La Center	70	[2] 23	Lake Keechelus	4	[2] 9	2.89	−0.41	Heather Meadows	14.93	Naches Heights	0.06
West Virginia	45.4	+2.4	Valley Chapel	89	18	Pickens	5	1	2.66	−1.24	Pickens	4.97	Upper Tract	0.20
Wisconsin	35.1	+6.1	Fond du Lac	76	16	Mellen	−22	1	2.10	+0.38	Plum Island	4.82	Florence	0.40
Wyoming	29.6	−0.3	2 stations	70	[2] 14	Riverside	−29	20	1.21	+0.19	Dome Lake	4.40	Powell	0.02
Alaska (February)	23.4	+3.9	Annex Creek	58	22	Eagle	−51	17	5.88	+0.70	Latouche	28.61	McKinley Park	0.11
Hawaii	70.7	+1.9	2 stations	90	[2] 24	Waimea	45	26	10.55	+1.67	Honokohau Ridge	61.00	Kaanapali	0.47
Porto Rico	73.8	0.0	2 stations	94	[2] 15	Cayey	48	8	7.24	+3.70	Jayuya	18.65	Santa Isabel	0.10

[1] For description of tables and charts, see REVIEW, January, p. 43.

[2] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, March, 1927*

Districts and stations	Elevation of instruments: Barometer above sea level	Thermometer above ground	Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Departure from normal	Days with 0.01, or more	Wind: Total movement	Prevailing direction	Maximum velocity: Miles per hour	Direction	Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
New England							37.4	+4.7										73	1.52	−2.3										5.0		
Eastport	76	67	85	29.94	30.03	+0.10	32.4	+3.5	55	16	38	14	2	26	23	30	26	70	2.22	−2.1	7	8,562	w.	40	n.	3	7	9	15	6.5	3.4	0.0
Greenville, Me.	1,070	6		28.85	30.05		29.0		58	13	39	−4	24	18	39				0.97		5	5,753	nw.	31	nw.	15	13	2	16		8.0	
Portland, Me.	103	82	117	29.96	30.09	+.13	35.6	+3.8	61	13	43	13	2	28	28	31	26	70	1.32	−2.4	7	6,686	nw.	36	n.	3	16	6	9	4.5	1.4	0.0
Concord	289	70	79	29.76	30.09	+.09	36.2	+5.4	63	16	46	5	5	26	44				0.92	−2.5	4	3,735	nw.	25	w.	31	15	10	6	3.9	0.6	0.0
Burlington	403	11	48	29.65	30.11	+.11	33.7	+4.6	65	17	42	7	2	25	36				1.05	−0.8	8	7,748	s.	38	s.	13	11	7	13	6.0	2.0	0.0
Northfield	876	12	60	29.13	30.11	+.11	31.0	+4.6	61	13	43	−9	2	20	40	27	23	80	0.99	−1.8	8	5,211	s.	32	nw.	9	9	12	10	5.9	3.9	0.0
Boston	125	115	188	29.94	30.08	+.11	41.6	+6.0	69	14	50	16	3	34	29	35	27	62	1.19	−2.9	7	7,727	w.	36	sw.	8	13	12	6	4.3	0.6	0.0
Nantucket	12	14	90	30.05	30.06	+.08	39.2	+3.7	59	19	45	19	4	33	22	36	33	82	2.14	−1.8	9	12,364	sw.	69	ne.	3	12	7	12	5.6	T.	0.0
Block Island	26	11	46	30.04	30.07	+.09	38.8	+3.4	58	19	44	18	3	33	21	35	31	79	1.81	−2.6	9	12,979	sw.	64	n.	3	11	11	9	4.7	1.1	0.0
Providence	160	215	251	29.91	30.09	+.11	40.6	+4.9	66	13	49	14	4	32	30	34	27	63	1.47	−3.2	9	9,521	nw.	54	nw.	8	12	12	7	4.6	0.1	0.0
Hartford	159	122		29.92	30.10	+.11	41.6	+6.6	73	17	50	17	4	33	34				1.72	−2.6	9		nw.				16	7	8	4.3	2.1	0.0
New Haven	106	74	153	29.90	30.11	+.12	40.6	+4.8	64	17	49	17	4	33	27	35	31	72	1.80	−2.6	10	6,724	n.	37	ne.	2	13	6	12	4.7	1.4	0.0
Middle Atlantic States							44.8	+4.2										73	1.59	−2.1										5.7		
Albany	97	102	115	30.01	30.12	+.11	38.6	+5.9	70	17	47	11	2	30	40	34	29	72	1.72	−1.0	11	5,671	s.	30	s.	8	15	7	9	4.5	2.7	0.0
Binghamton	871	10	84	29.17	30.12	+.10	37.6	+5.0	74	17	47	8	2	29	43				2.21	−0.4	13	4,462	nw.	24	sw.	13	8	6	17	6.7	1.1	0.0
New York	314	414	454	29.76	30.11	+.11	42.6	+4.9	72	18	50	17	3	35	26	36	30	66	1.18	−2.9	12	11,506	nw.	64	nw.	8	9	10	12	6.0	0.2	0.0
Harrisburg	374	94	104	29.72	30.13	+.10	43.8	+4.9	78	17	52	22	2	36	37	38	30	63	1.98	−1.1	8	5,295	nw.	36	n.	2	8	8	15	6.2	T.	0.0
Philadelphia	114	123	190	30.00	30.13	+.11	46.4	+5.6	77	18	54	23	3	38	27	42	38	79	1.11	−2.3	10	7,393	n.	42	n.	2	10	8	13	5.9	T.	0.0
Reading	325	81	98	29.75	30.12		44.2		78	18	53	21	3	36	38	38	32	68	1.40	−2.1	11	5,060	nw.	29	nw.	3	8	9	14	6.3	T.	0.0
Scranton	805	111	119	29.24	30.12	+.10	40.0	+4.3	76	17	49	12	2	31	40	30	32	78	1.99	−1.1	10	5,191	n.	34	w.	8	8	11	12	5.7	T.	0.0
Atlantic City	52	37	172	30.05	30.11	+.09	42.4	+3.8	66	18	49	19	4	36	23	36	35	80	1.28	−2.4	10	13,422	s.	60	ne.	2	12	10	9	5.0	T.	0.0
Cape May	17	13	49	30.11	30.13	+.12	42.8	+2.0	61	31	50	21	3	30	23	40	37	87	1.53		10		nw.								0.5	0.0
Sandy Hook	22	10	55	30.08	30.10		41.0		70	18	47	21	3	35	28	36	32	74	1.29		11	10,797	w.	61	n.	2	8	12	11	5.6	T.	0.0
Trenton	190	159	183	29.90	30.11		43.4		77	17	53	19	4	34	35	37	32	71	0.83	−3.2	9	8,288	nw.	48	nw.	8	9	10	12	5.9	T.	0.0
Baltimore	123	100	215	29.98	30.12	+.09	47.4	+5.1	79	18	55	24	4	40	27	41	35	68	1.47	−2.4	8	7,617	nw.	44	sw.	8	8	8	15	5.9	T.	0.0
Washington	112	62	85	29.99	30.12	+.08	47.6	+5.0	80	18	56	21	4	39	35	41	35	67	1.27	−2.6	8	5,437	nw.	32	nw.	8	8	8	15	5.8	T.	0.0
Cape Henry	18	8	54	30.08	30.10		50.0		85	19	58	28	4	42	32	45	41	77	2.00	−2.3	9	11,328	sw.	62	n.	2	10	10	11	5.3	7.0	0.0
Lynchburg	681	153	188	29.36	30.12	+.07	51.2	+3.9	85	18	62	23	5	40	41	44	38	67	1.29	−2.5	10	6,066	nw.	40	n.	2	12	8	11	5.2	2.7	0.0
Norfolk	91	170	205	30.03	30.12	+.09	51.6	+3.4	82	19	60	25	3	43	29	45	40	72	2.18	−2.1	9	10,370	s.	52	n.	2	11	8	12	5.5	11.0	0.0
Richmond	144	11	52	29.97	30.13	+.09	50.2	+3.0	84	19	61	23	5	40	36	43	38	72	1.95	−1.8	12	6,618	sw.	46	w.	10	8	12	11	5.7	1.3	0.0
Wytheville	2,304	49	55	27.70	30.12	+.07	44.9	+2.6	74	20	54	18	5	36	36	39	35	73	1.53	−2.9	13	5,097	w.	33	w.	20	8	10	13	5.9	5.6	0.0
South Atlantic States							55.9	+2.2										77	3.02	−1.1										5.7		
Asheville	2,253	70	84	27.74	30.13	+.07	47.6	+2.7	78	18	57	21	3	38	34	42	37	73	2.79	−1.2	12	7,302	se.	34	nw.	2	10	7	14	6.1	7.5	0.0
Charlotte	779	55	62	29.28	30.13	+.08	53.6	+3.2	83	19	63	23	4	44	29	46	41	68	3.83	−0.7	13	4,626	sw.	24	sw.	26	8	7	16	6.1	13.3	0.0
Hatteras	11	11	50	30.10	30.10	+.06	52.6	+0.6	75	18	59	30	4	46	22	49	46	82	3.82	−1.6	12	12,608	ne.	74	nw.	2	11	7	13	5.1	T.	0.0
Raleigh	376	103	110	29.71	30.12	+.07	52.8	+2.6	84	19	63	24	4	43	31	46	41	72	2.78	−1.5	12	6,957	sw.	33	nw.	8	11	7	13	5.4	17.8	0.0
Wilmington	78	81	91	30.05	30.14	+.09	55.6	+2.3	82	18	65	27	4	46	28	51	48	83	2.39	−1.2	7	5,962	sw.	29	ne.	2	13	5	13	5.2	4.5	0.0
Charleston	48	11	92	30.08	30.13	+.07	58.9	+1.5	80	19	66	32	3	52	23	54	52	84	2.97	−0.8	7	7,134	sw.	35	e.	24	15	3	13	5.3	T.	0.0
Columbia, S. C.	351	41	57	29.75	30.14	+.08	57.0	+1.8	84	19	66	27	4	48	30	50	44	70	3.82	+0.1	8	5,820	ne.	29	ne.	9	9	8	14	6.1	0.7	0.0
Due West	711	10	55	29.37	30.16		54.4		81	18	64	23	3	45	29				3.65		10	7,190	sw.	33	e.	9	8	7	16	6.0	3.1	0.0
Greenville, S. C.	1,039	139	146	29.01	30.12		53.8	+3.9	80	19	62	27	3	45	29	48	43	75	3.89		12	7,812	ne.	37	sw.	26	8	10	13	6.1	9.7	0.0
Augusta	182	62	77	29.92	30.12	+.06	58.4	+2.4	84	20	68	29	3	49	34	53	50	81	3.34	−1.5	11	4,239	nw.	22	w.	26	7	9	15	6.1	T.	0.0
Savannah	65	150	194	30.06	30.12	+.06	60.8	+1.8	83	21	69	32	3	52	29	54	52	80	2.81	−0.8	7	8,950	s.	43	w.	24	8	10	13	5.9	0.0	0.0
Jacksonville	43	200	245	30.08	30.12	+.06	64.2	+1.6	83	20	72	32	3	56	28	57	53	75	1.67	−1.8	7	9,069	sw.	43	nw.	2	12	8	11	5.3	0.0	0.0
Florida Peninsula							70.4	+0.6										73	1.42	−0.9										4.2		
Key West	22	10	64	30.07	30.09	+.04	73.5	+0.9	85	21	79	55	4	68	16	66	63	74	0.83	−0.6	5	8,586	se.	39	nw.	3	19	7	5	3.5	0.0	0.0
Miami	25	71	79	30.09	30.12		70.2	0.0	83	22	76	30	3	65	27	63	59	69	0.88	−1.7	6	6,436	e.	27	e.	30	12	12	7	4.5	0.0	0.0
Tampa	35	79	87	30.08	30.12	+.05	67.6	+0.8	86	17	77	37	3	58	29	60	56	75	2.55	−0.3	8	4,688	e.	26	sw.	1	12	10	9	4.7	0.0	0.0
Titusville	44	5		30.07	30.12		66.6		88	21	78	32	3	56	37				2.29		6		sw.				13	13	5	4.0	0.0	0.0
East Gulf States							58.7	+1.0										74	4.97	−0.9										5.5		
Atlanta	173	190	216	28.87	30.12	+.06	54.8	+2.8	80	19	63	25	3	47	26	48	43	70	3.31	−2.5	12	9,394	nw.	46	nw.	2	8	6	17	6.1	0.6	0.0
Macon	1,370	78	87	29.72	30.12	+.06	58.3	+1.6	83	19	68	28	4	48	34	51	46	70	2.74	−2.7	9	5,030	s.	28	n.	9	10	6	15	5.7	T.	0.0
Thomasville	273	49	58	29.82	30.12	+.06	61.8	+1.6	84	18	72	29	3	51	31	54	49	73	1.47	−3.6	8	3,872	sw.	22	sw.	9	7	13	11	5.9	0.0	0.0
Apalachicola	36	42	49	30.08	30.12		61.6		76	16	68	35	3	55	21	57	55	83	1.72		5	6,206	s.	29	nw.	2	17	9	5	3.6	0.0	0.0
Pensacola	56	149	185	30.05	30.12	+.06	60.8	+0.5	75	19	67	32	3	54	26	57	54	81	3.60	−1.8	7	10,635	s.	45	se.	1	10	12	9	5.2	0.0	0.0
Anniston	741	9	57	29.35	30.15	+.09	54.8	+2.3	84	19	65	22	4	44	37				5.11	−0.7	13	4,931	s.	26	se.	1	11	7	13	5.3	T.	0.0
Birmingham	700	11	48	29.36	30.13	+.07	55.6	+0.2	82	19	65	25	3	46	31	49	43	70	6.14	+0.4	11	6,487	s.	40	se.	13	12	5	14	5.5	T.	0.0
Mobile	57	125	161	30.05	30.11	+.06	60.8	+1.1	79	28	69	31	3	53	26	55	52	80	6.27	−0.9	9	8,706	s.	43	se.	1	10	10	11	5.2	0.0	0.0
Montgomery	223	100	112	29.88	30.13	+.07	59.0	+1.2	84	19	68	29	3	50	29	52	46	67	3.28	−2.1	9	5,743	s.	34	nw.	2	11	9	11	5.4	T.	0.0
Corinth	469	6					54.4		82	19	64	24	4	45	34				10.18		15		s.				5	18	8		T.	0.0
Meridian	375	87	95	29.70	30.10	+.05	57.5	+0.4	84	18	68	28	3	48	33	51	46	71	6.14	+0.5	12	5,301	nw.	32	nw.	2	10	6	15	5.9	0.0	0.0
Vicksburg	247	65	73	29.83	30.12	+.08	58.6	+0.1	83	31	67	32	3	50	29	52	48	74	8.57	+2.3	11	6,243	s.	33	w.	12	9	5	17	6.0	0.0	0.0
New Orleans	53	76	84	30.05	30.10	+.06	63.5	+0.7	83	31	71	36	3	56	25	57	54	77	7.99	+2.7	8	5,652	s.	22	se.	11	8	7	16	6.1	0.0	0.0
West Gulf States							59.5	+0.3										72	3.11	+0.1										5.9		
Shreveport	249	77	93	29.81	30.09	+.07	59.0	+0.7	84	18	68	31	3	50	32	52	48	73	5.02	+0.5	9	5,328	se.	30	ne.	8	10	6	15	5.8	0.0	0.0
Bentonville	303	11	44				48.8	+1.5	79	19	59	11	3	38	38				6.08		13	5,723	s.	28	s.	25	13	12	6		3.2	0.0
Fort Smith	1,457	79	94	29.56	30.04	+.03	52.8	+0.2	82	19	62	25	3	43	37	46	40	68	2.93	−0.7	11	7,244	e.	39	w.	31	10	6	15	5.9	T.	0.0
Little Rock	357	136	144	29.69	30.08	+.05	54.0	+1.0	81	19	63	26	3	45	35	47	41	68	6.89	+2.0	16	7,487	s.	34	s.	5	9	8	14	5.8	0.0	0.0
Austin	605	136	148	29.40	30.04		61.4	+0.7	86	31	71	30	2	52	36				3.22	+0.9	8	7,632	se.	40	nw.	7	10	8	13	5.8	0.0	0.0
Brownsville	57	53	61	29.93	29.98		68.3	+0.1	86	31	76	44	21	61	36	62	59	80	0.17		4	8,585	s.	32	s.	16	7	14	10	5.7	0.0	0.0
Corpus Christi	20	11	78	30.01	30.06	+.05	64.6	−0.4	86	31	71	38	2	59	30	60	57	81	1.50	−0.4	6	11,187	se.	39	se.	31	7	6	18	6.7	0.0	0.0
Dallas	512	220	227	29.49	30.04		57.0		79	18	66	29	2	48	36				4.64		6	11,380	se.	48	sw.	31	10	10	11	5.4	T.	0.0
Fort Worth	670	106	114	29.32	30.04	+.06	56.6	−1.1	81	18	66	29	2	47	36	49	42	61	2.19	0.0	7	8,450	s.	32	s.	25	11	9	11	5.4	0.0	0.0
Galveston	54	106	114	30.02	30.08	+.07	62.8	+0.4	74	29	68	39	2	58	24	58	55	81	0.96	−1.9	6	9,430	se.	42	n.	21	10	7	14	5.8	0.0	0.0
Groesbeck	461	11	56	29.56	30.05		58.6		82	19	68	31	2	49	32				3.09		9	9,228	s.	36	sw.	25	8	7	16	6.4	0.0	0.0
Houston	138	292	314	29.92	30.07		63.0	−0.3	82	27	71	33	2	55	30				2.81	−0.6	8	11,767	se.	40	nw.	21	10	5	16	6.0	0.0	0.0
Palestine	510	64	72	29.52	30.06	+.06	59.0	−0.1	82	19	68	30	2	50	30	52	47	69	3.41	−0.1	7	6,957	s.	30	nw.	11	8	5	18	6.4	0.0	0.0
Port Arthur	34	58	66	30.03	30.07		62.5		77	27	69	34	2	56	30				2.13		7	6,725	se.	35	w.	20	11	5	15	5.8	0.0	0.0
San Antonio	693	119	132	29.29	30.02	+.04	63.2	+0.4	90	31	73	31	2	53	34	56	51	71	2.02	+0.3	8	6,703	se.	36	nw.	11	10	8	13	5.8	0.0	0.0
Taylor	583	55	63	29.45	30.07	+.06	60.0	+0.3	85	31	70	29	2	50	32				3.21	+0.7	8	7,589	se.	34	s.	25	9	9	13	5.4	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, March, 1927*—Continued

Districts and stations	Elevation of instruments: Barometer above sea level	Thermometer above ground	Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Departure from normal	Days with 0.01, or more	Wind: Total movement	Prevailing direction	Maximum velocity: Miles per hour	Direction	Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
Ohio Valley and Tennessee							47.8	+3.6										71	5.91	+1.5										6.6		
Chattanooga	762	189	213	29.30	30.12	+.06	53.0	+1.8	83	19	62	24	3	44	32	47	41	68	8.77	+2.6	13	6,383	se.	30	sw.	7	9	8	14	5.9	11.0	0.0
Knoxville	995	102	111	29.04	30.11	+.05	51.3	+2.6	82	19	61	21	3	42	31	46	42	75	3.95	−1.6	12	4,923	sw.	38	sw.	7	7	16	8	5.5	9.5	0.0
Memphis	399	76	97	29.66	30.09	+.05	53.4	+1.1	79	19	61	28	3	46	28	48	42	69	13.04	+7.3	15	6,421	sw.	39	w.	31	10	6	15	6.0	T.	0.0
Nashville	546	168	191	29.53	30.13	+.08	51.4	+2.2	77	20	60	24	3	43	29	46	41	72	9.66	+4.2	16	7,725	s.	44	se.	13	8	6	17	6.5	2.7	0.0
Lexington	989	193	230	29.04	30.13	+.08	47.7	+4.0	75	16	56	20	2	39	32				5.17	+0.4	11	10,128	sw.	40	nw.	7	7	8	16	6.5	3.5	0.0
Louisville	525	188	234	29.53	30.12	+.07	48.4	+3.0	75	16	56	22	2	41	28	43	37	68	7.01	+2.7	12	8,148	s.	45	se.	13	7	7	17	6.4	3.5	0.0
Evansville	431	76	116	29.65	30.13	+.09	48.6	+2.7	76	19	56	24	2	42	26	44	39	71	8.15	+3.6	10	6,763	s.	40	sw.	20	4	16	11	6.3	2.8	0.0
Indianapolis	822	194	230	29.20	30.10	+.06	44.9	+4.9	72	16	53	20	2	37	28	39	33	69	6.32	+2.3	9	9,722	s.	40	se.	12	5	9	17	7.0	T.	0.0
Royal Center	736	11	55	29.29	30.11		41.4		70	16	50	17	4	33	31				4.20		12	8,672	s.	35	se.	19	5	11	15	6.7	T.	0.0
Terre Haute	575	96	129	29.46	30.09		46.0		72	16	54	22	2	38	28	40	36	74	7.58		10	8,117	s.	36	se.	12	5	11	15	6.7	0.3	0.0
Cincinnati	627	11	51	29.43	30.12	+.07	46.1	+5.2	75	16	55	20	2	37	34	41	36	73	3.65	0.0	10	6,257	s.	40	se.	13	8	4	19	6.7	T.	0.0
Columbus	822	179	222	29.23	30.12	+.08	44.0	+4.9	72	16	52	21	2	36	28	40	35	74	3.97	+0.8	9	7,862	s.	41	nw.	26	6	7	18	6.9	T.	0.0
Dayton	899	137	173	29.15	30.12		44.8	+4.3	73	16	53	19	2	37	31	39	35	71	4.05	+0.6	12	7,421	ne.	36	s.	13	6	8	17	7.0	T.	0.0
Elkins	1,947	59	67	28.04	30.15	+.10	43.7	+3.7	75	20	54	14	5	34	41	38	33	76	2.81	−1.3	12	4,622	w.	35	nw.	8	6	4	21	7.5	T.	0.0
Parkersburg	637	77	82	29.47	30.14	+.09	47.0	+4.2	76	12	56	23	4	38	38	40	35	69	3.10	−0.7	13	4,676	se.	33	nw.	26	8	2	21	7.1	T.	0.0
Pittsburgh	842	353	410	29.19	30.12	+.08	44.8	+5.2	74	13	52	19	3	37	34	39	34	70	3.20	+0.2	13	8,857	w.	44	w.	26	4	7	20	7.5	T.	0.0
Lower Lake Region							38.7	+5.7										75	2.20	−0.4										6.5		
Buffalo	767	247	280	29.25	30.10	+.08	36.2	+5.1	69	13	43	9	2	30	28	33	30	82	1.76	−0.9	13	11,028	sw.	54	sw.	7	9	5	17	6.7	3.5	0.0
Canton	448	10	61	29.60	30.10		32.8	+5.1	64	17	41	2	4	25	33				1.55	−1.3	8	7,219	sw.	37	w.	8	14	3	14	5.3	3.7	T.
Oswego	335	76	91		30.11	+.10	36.6	+5.4	73	17	44	10	2	30	35			80	1.72	−1.1	11	7,575	se.	33	w.	9	9	6	16		1.3	0.0
Rochester	523	86	102	29.53	30.12	+.10	39.0	+7.2	76	17	46	13	2	32	32	34	28	70	1.81	−1.1	9	6,239	w.	36	w.	8	9	6	16	6.5	4.7	0.0
Syracuse	597	97	113	29.46	30.12	+.10	38.1	+6.7	73	17	45	12	2	31	33				2.50	+0.1	12	6,056	s.	33	nw.	8	7	8	16	6.8	7.2	0.0
Erie	714	130	166	29.31	30.10	+.08	39.4	+5.9	72	17	46	13	2	33	26	35	30	73	2.25	−0.4	12	9,875	nw.	42	se.	7	7	10	14	6.4	0.2	0.0
Cleveland	762	190	201	29.27	30.11	+.08	40.3	+5.7	70	12	46	16	2	34	30	37	33	76	3.62	+0.8	11	9,624	s.	42	w.	7	3	8	20	7.4	T.	0.0
Sandusky	629	62	70	29.41	30.11	+.08	41.0	+5.9	71	16	48	20	2	34	30				2.97	+0.4	12	6,563	sw.	32	w.	26	3	13	15	7.0	T.	0.0
Toledo	628	208	243	29.41	30.11	+.08	41.4	+6.1	70	16	48	18	1	35	28	37	32	74	2.31	0.0	12	9,878	s.	43	w.	26	7	10	14	6.1	T.	0.0
Fort Wayne	856	113	124	29.16	30.10		41.4	+2.5	71	16	49	18	2	34	34	37	32	74	3.34		11	7,004	s.	32	w.	26	6	14	11	6.2	T.	0.0
Detroit	730	218	258	29.30	30.11	+.08	40.0	+6.6	67	16	46	17	2	33	26	35	29	69	1.53	−0.8	14	7,556	s.	35	w.	26	5	11	15	6.8	1.0	0.0
Upper Lake Region							35.3	+6.9										79	2.05	−0.2										6.0		
Alpena	609	13	92	29.42	30.11	+.08	31.8	+6.3	58	17	38	7	2	25	31	29	25	80	2.50	+0.5	12	5,670	se.	34	w.	17	13	8	10	5.0	11.6	0.0
Escanaba	612	54	60	29.41	30.09	+.05	31.8	+7.6	55	17	38	5	1	25	24	28	25	81	2.16	+0.2	13	7,497	s.	36	n.	26	8	8	15	5.7	4.2	0.0
Grand Haven	632	54	89	29.39	30.09	+.06	37.5	+5.8	64	16	45	12	1	30	28	34	31	82	2.90	+0.4	11	8,058	s.	31	w.	8	9	8	14	6.2	1.5	0.0
Grand Rapids	707	70	87	29.31	30.10	+.07	39.8	+6.4	70	16	47	14	1	32	26	34	29	71	2.30	−0.3	11	4,580	s.	23	nw.	30	3	12	16	7.3	1.0	0.0
Houghton	668	62	99	29.33	30.08	+.04	29.8	+7.0	54	15	37	−2	1	23	29				1.41	−0.7	9	6,806	e.	35	w.	30	9	7	15	6.1	4.1	T.
Lansing	878	11	62	29.13	30.10		38.0	+5.8	70	16	46	13	2	30	32	34	31	84	1.55	−0.7	13	4,926	s.	22	sw.	13	10	10	11	5.6	0.5	0.0
Ludington	637	60	66	29.36	30.06		36.6		62	16	42	10	1	31	22	33	30	80	3.08		11	7,679	s.	31	s.	29	12	6	13	5.5	2.4	0.0
Marquette	734	77	111	29.27	30.09	+.05	32.8	+8.0	59	16	39	8	1	27	22	29	25	78	2.17	+0.1	10	7,447	s.	38	sw.	15	8	6	17	6.7	3.8	T.
Port Huron	638	70	120	29.39	30.09	+.06	37.3	+6.9	64	16	44	15	2	31	29	33	30	80	1.25	−1.2	13	8,448	s.	40	w.	30	5	14	12	6.0	0.9	0.0
Saginaw	641						37.6	+6.1	71	16	46	11	2	29	35				2.18		11		n.				7	9	15		0.0	
Sault Ste. Marie	614	11	52	29.40	30.12	+.09	29.5	+7.9	51	16	37	−2	1	22	32	27	24	81	1.83	0.0	11	6,267	se.	38	nw.	8	11	6	14	5.0	5.3	T.
Chicago	673	7	131	29.35	30.09	+.06	42.0	+6.7	71	16	48	24	4	36	28	37	32	73	2.69	+0.1	12	9,348	s.	38	ne.	20	9	6	16	6.4	0.4	0.0
Green Bay	617	109	141	29.39	30.07	+.03	36.0	+7.4	70	16	43	9	1	29	27	32	30	88	2.17	−0.2	12	8,658	s.	33	n.	26	8	11	12	5.8	10.6	0.0
Milwaukee	681	125	139	29.32	30.08	+.05	39.5	+7.4	68	16	46	18	1	32	24	35	30	73	2.40	−0.3	12	7,594	se.	35	e.	20	11	5	15	6.0	6.8	0.0
Duluth	1,333	5	47	28.81	30.07	+.01	30.6	+6.9	52	15	38	8	1	24	25	27	23	79	1.46	−0.1	10	9,371	ne.	41	sw.	17	9	9	13	5.7	6.0	0.0
North Dakota							30.6	+8.6										76	0.97	0.0										5.8		
Moorhead	940	50	58	29.01	30.06	−.02	31.0	+8.3	61	15	38	4	27	24	30	28	25	79	1.85	+0.7	10	6,767	s.	24	n.	9	4	10	17	7.2	17.5	T.
Bismarck	1,674	8	57	28.21	30.04	−.02	31.9	+7.7	65	14	41	10	19	23	34	27	22	71	0.90	−0.1	6	8,279	nw.	35	nw.	22	10	11	10	5.2	9.0	0.0
Devils Lake	1,478	11	44	28.42	30.04	−.01	29.0	+10.5	60	15	37	5	1	21	27	26	23	82	0.86	−0.2	10	7,636	se.	33	n.	23	11	9	11	5.3	7.4	0.0
Ellendale	1,457	10	56	28.45	30.05		32.3		62	15	41	10	2	23	32				0.56		9	11,679	nw.	48	nw.	22	5	11	15	6.6	5.3	0.0
Grand Forks	833	12	67				30.8		59	15	38	2	2	24	28				0.54		5		nw.	40	se.	3	10	12	9		4.3	0.0
Williston	1,878	41	48	27.98	30.01	−.03	30.6	+7.7	62	14	39	3	19	22	26	27	22	72	0.28	−0.4	5	7,531	w.	33	w.	22	13	9	9	4.6	2.4	0.0
Upper Mississippi Valley							41.8	+5.7										74	3.99	+1.6										6.1		
Minneapolis	918	102	206	29.01	30.02		35.5	+5.9	69	15	43	10	2	28	27				2.43	+0.8	10	8,632	nw.	37	s.	15	8	4	19	6.7	4.1	0.0
St. Paul	837	236	261	29.13	30.06	+.01	5.4	+6.3	67	15	43	11	2	28	28				2.07	+0.5	10	9,358	nw.	41	se.	15	8	9	14	6.2	8.5	0.9
La Crosse	714	11	48	29.25	30.04	.03	38.8	+7.3	71	16	47	14	3	30	31	34	29	75	2.21	+0.6	13	4,034	se.	20	s.	4	8	10	13	6.2	3.4	0.0
Madison	974	70	78	29.01	30.09	+.05	38.3	+7.7	70	16	46	11	3	31	30	34	29	77	2.23	0.0	12	7,517	s.	30	ne.	19	12	3	16	5.9	6.7	0.0
Wausau	1,247	4		28.71	30.08		34.5		68	16	42	2	1	27	34				2.76		15						9	8	14	6.3	14.7	1.0
Charles City	1,015	10	49	28.96	30.06	+.01	38.0	+7.3	69	15	47	13	3	29	31	33	29	79	1.83	−0.1	12	5,624	se.	26	s.	15	9	11	11	5.6	7.0	0.0
Davenport	606	71	79	29.40	30.07	+.01	42.4	+6.3	72	16	50	18	2	34	27	38	31	80	3.13	+0.9	12	5,755	s.	33	e.	31	8	7	16	6.4	0.5	0.0
Des Moines	861	84	97	29.11	30.04	.00	41.1	+5.2	73	15	50	18	2	32	31	36	31	72	2.55	+0.9	11	6,044	sw.	35	sw.	15	9	8	14	6.2	0.9	0.0
Dubuque	700	81	96	29.28	30.04	.00	40.1	+6.1	71	16	48	17	2	32	29	36	30	73	2.18	0.0	12	5,271	s.	24	s.	16	10	7	14	6.2	2.7	0.0
Keokuk	614	64	78	29.38	30.07	+.04	44.4	+5.5	73	16	53	19	2	36	29	39	33	70	3.48	+1.1	10	6,317	se.	35	s.	12	8	11	12	5.7	0.9	0.0
Cairo	358	87	93	29.71	30.10	+.06	50.0	+2.8	72	16	57	23	2	43	28	45	40	71	8.07	+4.0	15	7,601	se.	60	sw.	31	7	8	16	6.4	0.0	0.0
Peoria	609	11	45	29.41	30.09	+.06	43.2	+6.2	72	16	51	20	2	35	29	38	34	76	4.55	+1.6	10	5,827	s.	29	e.	31	12	4	15	6.3	3.3	0.0
Springfield, Ill.	636	10	91	29.39	30.07	+.04	45.0	+4.8	72	16	52	21	2	38	28	40	35	72	6.59	+3.5	11	7,043	s.	34	ne.	31	11	4	15	5.6	0.3	0.0
Hannibal	534	74	109	29.49	30.07	+.05	45.4	+4.4	75	16	54	17	3	37	31				6.87	+4.1	11	7,173	s.	36	e.	19	11	6	14	5.8	1.9	0.0
St. Louis	568	265	303	29.46	30.07	+.04	47.9	+4.1	75	16	56	22	2	40	28	42	37	72	7.67	+4.2	12	10,370	s.	56	sw.	5	9	7	15	6.1	3.0	0.0
Missouri Valley							40.9	+3.4										71	3.78	+1.8										5.7		
Columbia, Mo.	784	11	84	29.22	30.07	+.04	46.0	+3.4	76	16	56	14	2	36	30				7.65	+4.6	12	7,027	se.	40	sw.	18	11	5	15	5.8	4.2	0.0
Kansas City	963	161	181	28.99	30.04	+.02	45.5	+2.8	74	15	54	20	3	37	27	39	34	70	4.60	+1.8	11	8,420	s.	38	ne.	19	10	9	12	5.7	3.1	0.0
St. Joseph	967	11	49	28.98	30.03		43.9		74	15	54	19	3	35	32	38	32	71	3.96		7	7,353	se.	32	e.	31	12	6	13	5.2	3.4	0.0
Springfield, Mo.	1,324	98	104	28.62	30.04	+.02	46.8	+1.6	74	19	56	18	3	38	32	41	35	71	7.46	+3.4	14	9,540	se.	39	w.	5	20	5	6	3.6	6.5	0.0
Iola	984	11	50	28.98	30.05	+.04	45.8	+1.3	74	15	55	18	3	35	38				5.50	+2.6	9	6,187	s.	34	nw.	18	14	7	10	5.0	2.6	0.0
Topeka	987	92	107				44.2	+1.6	74	15	54	19	3	35	31				5.31	+3.0	9	7,918	s.	32	se.	9	14	5	12	5.0	3.1	0.0
Lincoln	1,189	11	84	28.74	30.03	+.01	41.0	+3.5	74	15	50	17	21	32	31	35	30	71	2.76	+1.4	10	8,908	s.	42	ne.	18	6	9	16	7.0	2.7	0.0
Omaha	1,105	115	122	28.83	30.04	.00	41.0	+4.0	75	15	50	17	2	32	32	36	30	69	1.88	+0.5	10	6,954	s.	36	ne.	19	11	8	12	5.5	4.0	0.0
Valentine	2,598	47	54	27.27	30.05	+.02	34.2	+1.9	66	8	44	0	21	24	43	29	24	69	2.59	+1.4	12	8,980	n.	39	nw.	25	3	17	11	6.4	23.3	2.5
Sioux City	1,135	94	164	28.81	30.06	+.01	37.8	+5.1	70	15	46	12	21	30	29	34	30	78	2.16	+0.9	14	10,120	s.	48	nw.	25	5	11	15	6.8	5.8	0.0
Huron	1,306	59	74	28.62	30.06	.00	34.8	+5.9	67	15	45	11	2	25	43	30	25	74	1.52	+0.5	6	8,533	s.	37	s.	3	9	10	12	5.8	8.5	0.0
Pierre	1,572	70	75		30.06	.00	37.0	+5.5	69	8	48	13	1	26	45			68	0.93	−0.4	7	8,623	nw.	40	nw.	22	6	15	10		7.3	2.5
Yankton	1,233	49	57	28.70	30.04	−.01	37.0	+3.8	68	15	45	10	21	29	34				3.01	+1.9	10	7,174	nw.	34	nw.	25	6	11	14	6.7	7.8	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, March, 1927*—Continued

Districts and stations	Elevation of instruments			Pressure			Temperature of the air												Precipitation			Wind										
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Total	Departure from normal	Days with 0.01, or more	Total movement	Prevailing direction	Maximum velocity: Miles per hour	Maximum velocity: Direction	Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
Northern Slope							33.0	+1.7										66	0.97	-0.1										5.8		
Billings	3,140	5					37.0		72	14	50	-1	19	24	45				0.32		2		nw.				14	7	10			
Havre	2,505	11	44	27.30	30.00	.00	32.6	+5.5	61	30	42	5	19	23	35	28	22	69	0.49	0.0	7	5,700	sw.	36	w.	8	8	16	7	5.5	3.5	0.0
Helena	4,110	87	112	25.73	29.99	-.02	35.7	+3.3	61	13	45	10	19	26	32	29	20	55	0.70	0.0	7	6,542	sw.	33	sw.	14	3	14	14	6.9	1.3	T.
Kalispell	2,973	48	56	26.88	30.00	+.01	33.8	+0.9	56	30	42	17	9	26	27	30	24	69	0.69	-0.4	9	3,807	nw.	37	sw.	8	4	15	12	6.4	6.7	0.0
Miles City	2,371	48	55	27.46	30.07	+.05	35.2	+6.6	69	14	45	10	1	26	34	30	25	69	0.23	-0.5	4	5,616	se.	39	nw.	22	17	4	10	4.6	1.2	0.4
Rapid City	3,259	50	58	26.58	30.08	+.07	34.6	+2.0	69	14	46	-2	1	24	41	29	22	65	2.23	+1.2	5	6,461	n.	32	n.	8	8	13	10	5.6	16.4	15.3
Cheyenne	6,088	84	101	23.90	30.01	+.05	30.8	-2.3	59	28	40	-2	1	21	42	26	19	65	1.93	+1.0	13	10,600	w.	48	w.	15	7	9	15	6.5	16.2	T.
Lander	5,372	60	68	24.56	30.02	+.03	31.8	-0.6	57	21	43	0	1	21	36	27	21	67	0.57	-1.0	9	4,220	w.	48	sw.	28	6	22	3	5.3	3.7	0.0
Sheridan	3,790	10	47	26.04	30.02		34.3		68	14	40	5	10	23	35	28	20	62	0.98		9	4,659	nw.	34	nw.	15	10	14	7	5.6	6.1	0.0
Yellowstone Park	6,241	11	48	23.79	30.05	+.03	20.7	+0.2	51	30	37	-1	20	17	35	23	17	66	0.65	-1.5	12	6,550	s.	36	s.	5	6	13	12	6.1	6.6	T.
North Platte	2,821	11	51	27.07	30.06	+.06	35.9	-0.7	66	24	46	2	21	26	38	30	25	73	1.26	+0.4	11	7,341	n.	54	ne.	11	10	8	13	5.9	9.8	0.0
Middle Slope							42.3	-1.0										66	2.26	+0.8										5.4		
Denver	5,292	106	113	24.65	30.00	+.05	36.0	-3.3	66	28	47	1	20	25	33	30	23	64	2.29	+1.3	12	5,422	s.	35	w.	31	11	11	9	5.3	19.1	0.0
Pueblo	4,685	80	86	25.21	29.96	+.04	38.8	-2.8	71	14	52	-7	1	25	44	31	22	58	1.18	+0.3	8	5,527	e.	42	w.	31	12	13	6	4.7	13.0	0.0
Concordia	1,392	50	58	28.52	30.03	+.02	42.2	+1.2	73	15	51	18	3	33	32	36	30	68	2.24	+0.8	8	7,358	s.	33	nw.	23	5	10	16	6.7	1.3	0.0
Dodge City	2,500	11	51	27.38	30.03	+.06	41.8	-1.0	78	15	54	6	1	30	42	35	27	70	1.73	+0.8	9	9,550	nw.	40	ne.	18	12	9	10	4.8	1.9	0.0
Wichita	1,358	139	158	28.56	30.01	+.02	44.9	-0.2	72	15	54	15	2	36	29	40	34	70	3.90	+1.6	9	11,077	s.	54	s.	11	9	11	11	5.5	3.8	0.0
Broken Arrow	756	11	56	29.22	30.05		49.3		76	18	60	22	3	39	39				2.92		8	11,247	s.	40	se.	9	9	11	11	5.7	1.5	0.0
Oklahoma City	1,214	10	47	28.73	30.03	+.05	50.0	0.0	76	30	61	19	2	39	39	43	37	68	2.23	-0.2	8	9,390	s.	37	w.	31	10	10	11	4.8	0.3	0.0
Southern Slope							54.8	+0.2										50	0.52	-0.5										3.6		
Abilene	1,738	10	52	28.19	30.01	+.05	56.9	+0.4	87	27	69	24	2	45	39	47	39	60	0.99	-0.4	6	8,795	s.	50	w.	31	13	9	9	4.4	0.0	0.0
Amarillo	3,676	10	49	26.22	29.97	+.02	48.0	+1.1	79	24	63	13	1	34	45	37	27	55	0.46	-0.2	3	7,532	sw.	34	sw.	4	21	5	5	3.1	0.0	0.0
Del Rio	944	64	71	29.01	30.00	+.05	63.1	-0.4	89	31	73	35	2	53	38				0.51	-0.7	5	8,491	se.	42	sw.	27	12	9	10	4.5	0.0	0.0
Roswell	3,566	75	85	26.32	29.93	+.03	51.0	-0.3	81	25	68	18	21	34	50	38	21	36	0.10	-0.6	2	6,963	s.	40	sw.	4	23	3	5	2.6	0.0	0.0
Southern Plateau							50.3	-0.4										49	0.39	-0.1										3.2		
El Paso	3,778	152	175	26.16	29.94	+.06	55.8	0.0	78	18	68	32	12	43	42	41	24	35	0.28	-0.1	3	7,695	w.	58	w.	10	21	6	4	2.5	T.	0.0
Santa Fe	7,013	38	53	23.17	29.93	+.04	39.6	-0.1	63	27	51	10	20	28	33	31	20	53	0.73	0.0	9	5,594	sw.	31	se.	19	16	8	7	4.2	2.6	0.0
Flagstaff	6,907	10	59	23.27	29.90	-.01	35.4	-0.5	62	24	48	6	12	23	40	30		69	1.34		9	6,857	nw.	31	sw.	18	15	11	5		5.0	T.
Phoenix	1,108	10	82	28.79	29.95	+.04	59.1	-1.6	87	24	73	35	12	45	30	47	33	45	0.24	-0.2	5	4,202	e.	44	w.	3	17	10	4	3.8	0.0	0.0
Yuma	141	9	54	29.82	29.97	+.03	62.3	-1.8	93	24	77	42	6	48	43	49	34	42	0.41	+0.1	3	4,440	n.	32	nw.	3	22	9	0	2.4	0.0	0.0
Independence	3,957	5	25	25.91	29.95	+.01	49.8	+1.3	80	24	65	23	15	35	41	37			0.28	-0.2	3		nw.				14	9	8		0.0	0.0
Middle Plateau							40.6	-0.3										60	1.71	+0.6										5.1		
Reno	4,532	74	81	25.44	30.02	+.04	41.9	+0.9	71	23	54	20	16	30	40	34	26	58	1.37	+0.5	7	5,133	w.	38	w.	8	12	11	8	4.5	4.6	1.3
Tonopah	6,090	12	20	23.99	29.96		39.8		65	24	49	17	15	30	28	33	25	58	0.43		6		nw.									
Winnemucca	4,344	18	56	25.61	30.04	+.03	39.4	-0.6	68	23	51	16	16	27	42	34	29	71	1.02	+0.1	11	5,814	ne.	46	sw.	31	10	17	4	4.9	6.5	T.
Modena	5,473	10	43	24.55	29.93	-.03	38.8	+0.6	68	24	51	18	21	27	41	32	23	50	1.50	+0.2	7	8,164	sw.	58	sw.	14	15	6	10	4.6	4.6	0.0
Salt Lake City	4,360	163	203	25.58	29.99	+.01	41.0	-0.7	64	27	49	21	15	33	34	34	25	55	2.97	+1.0	11	5,089	nw.	42	e.	30	8	10	13	6.0	9.9	0.0
Grand Junction	4,602	60	68	25.33	29.93	-.01	42.0	-1.6	69	27	53	17	21	31	35	35	26	58	1.70	+1.0	8	4,781	se.	33	s.	14	9	12	10	5.5	5.5	0.0
Northern Plateau							41.1	-0.4										64	1.28	-0.2										6.9		
Baker	3,471	48	53	26.44	30.08	+.05	37.2	-0.4	59	30	47	19	16	27	32	32	25	63	0.41	-1.0	11	4,618	se.	35	se.	7	3	10	18	7.4	1.5	0.0
Boise	2,739	78	86	27.18	30.07	+.04	42.0	-0.7	63	30	52	24	16	32	32	36	27	58	1.28	-0.2	7	4,255	se.	25	nw.	14	4	14	13	6.5	1.5	0.0
Lewiston	757	40	48	29.26	30.08	+.05	44.4	-1.0	71	30	54	29	25	35	37				1.51	+0.2	13	2,883	e.	26	nw.	21	4	10	17	7.0	T.	0.0
Pocatello	4,477	60	68	25.43	30.01	.00	37.4	0.0	57	29	46	11	19	29	28	31	24	61	1.26	-0.5	9	7,254	sw.	33	sw.	24	2	17	12	6.5	7.3	0.0
Spokane	1,929	101	110	27.96	30.04	+.03	40.0	+0.3	65	30	48	24	9	32	31	35	30	69	1.36	+0.2	12	4,230	sw.	28	sw.	7	5	7	19	7.4	2.6	0.0
Walla Walla	991	57	65	28.98	30.07	+.05	45.4	-0.7	67	30	53	33	27	38	28	41	35	68	1.84	0.0	14	4,133	s.	25	w.	17	6	9	16	6.6	0.1	0.0
North Pacific Coast Region							44.8	-0.4										79	3.32	-1.0										7.0		
North Head	211	11	56	29.88	30.11	+.10	44.0	-1.2	53	27	48	34	3	40	13	41	38	82	4.21	-0.5	20	11,188	n.	63	s.	7	0	9	22	8.2	0.0	0.0
Port Angeles	29	8	53		30.09		42.3		53	12	49	29	9	35	20				1.68	-0.5	15	4,991	sw.	36	w.	7	2	17	12		T.	0.0
Seattle	125	215	250	29.95	30.08	+.09	43.8	-1.1	58	29	50	33	3	38	20	40	35	73	2.69	0.0	16	7,033	s.	38	sw.	12	4	11	16	7.1	T.	0.0
Tacoma	194	172	201	29.88	30.10	+.10	44.5	+0.3	60	29	52	30	9	38	25				1.99	-1.5	17	6,072	s.	38	sw.	5	2	14	15	6.8	T.	0.0
Tatoosh Island	86	9	53	29.96	30.06	+.10	43.3	+0.4	50	28	46	36	8	40	9	41	38	84	8.44	-0.1	25	10,832	s.	65	s.	5	4	9	18	7.0	0.2	0.0
Yakima	1,071	5					43.6		68	23	57	22	28	31	44				0.18		6		nw.				2	21	8	5.8	T.	0.0
Medford	1,425	4					45.1		70	23	55	27	19	35	38	41	38	82	1.87		12		n.				3	13	15		1.0	0.0
Portland, Oreg	153	68	106	29.95	30.11	+.09	46.9	0.0	68	29	54	34	19	40	26	42	38	75	2.11	-2.6	17	4,312	nw.	20	sw.	31	3	11	17	7.5	0.0	0.0
Roseburg	510	9	57	29.57	30.13	+.09	46.0	-1.1	69	11	56	30	5	36	36	43	38	76	2.12	-1.9	18	2,255	nw.	23	w.	7	4	13	14	6.5	T.	0.0
Middle Pacific Coast Region							51.6	-0.6										76	1.94	-2.0										4.9		
Eureka	62	73	89	30.08	30.16	+.10	47.4	-0.9	60	29	54	35	15	41	19	45	43	84	3.95	-3.0	16	5,517	n.	28	n.	18	6	11	14	6.2	0.0	0.0
Point Reyes	490	7	18				49.2	-0.4	66	22	52	42	16	46	20				1.59		9	16,251	nw.	61	nw.	9	11	7	13		~~0.0~~	~~0.0~~
Red Bluff	332	50	56	29.70	30.06	+.02	53.2	-0.4	81	22	63	33	15	43	34	47	42	69	0.98	-2.8	6	4,624	nw.	26	se.	13	16	7	8	4.1	0.0	0.0
Sacramento	69	106	117	30.00	30.07	+.04	53.2	-1.1	79	23	62	37	16	45	28	49	45	73	1.01	-2.0	9	6,082	s.	31	nw.	18	16	8	7	4.1	0.0	0.0
San Francisco	155	208	243	29.91	30.08	+.02	54.2	0.0	76	23	61	44	15	48	25	49	45	76	2.19	-1.0	8	5,868	w.	31	w.	9	11	7	13	5.4	0.0	0.0
San Jose	141	12	110	29.94	30.09		52.6	-1.1	81	23	64	35	15	42	37				1.58	-1.0	10	4,611	nw.	29	nw.	14	12	8	11	4.9	0.0	0.0
South Pacific Coast Region							55.8	-0.2										70	1.88	-0.7										4.3		
Fresno	327	89	98	29.72	30.08	+.07	54.4	-0.6	79	23	64	36	16	45	29	48	41	65	1.28	-0.5	7	4,663	nw.	35	nw.	18	17	6	8	3.8	0.0	0.0
Los Angeles	338	159	191	29.68	30.04	+.02	57.4	-0.1	85	23	65	44	5	50	28	51	46	71	2.07	-0.9	6	4,188	ne.	29	w.	10	12	7	12	4.9	0.0	0.0
San Diego	87	62	70	29.95	30.04	+.02	56.6	-0.1	71	22	63	45	16	50	23	51	47	75	2.05	+0.4	9	4,733	nw.	29	s.	4	13	5	13	4.9	0.0	0.0
San Luis Obispo	201	32	40	29.88	30.10	+.04	54.7	0.0	85	23	65	39	29	44	38	47	41	68	2.10	-1.9	10	3,358	nw.	19	nw.	9	16	8	7	3.6	0.0	0.0
West Indies																																
San Juan, P. R.	82	9	54	29.92	30.01		75.0	-0.4	85	23	80	66	10	70	15				9.38	+6.2	20	8,244	e.	41	ne.	13	8	18	5	4.8	0.0	0.0
Panama Canal																																
Balboa Heights	118	7	97	29.78	29.87	+.01	81.9	+0.7	93	21	91	70	6	73	21	73	72	72	0.01	-0.6	1	9,020	nw.	34	n.	3	7	24	0	4.8	0.0	0.0
Colon	38	7	97	29.86	29.90	+.01	82.6	+2.0	89	30	88	73	1	77	13	75	73	76	1.27	-0.2	13	13,471	n.	30	n.	5	4	24	3	5.4	0.0	0.0
Alaska																																
Juneau	80	11	54	[1] 29.66	[1] 29.75		35.9		46	30	40	23	10	32	13	33	29	76	8.65		22	7,239	se.	32	e.	30	3	1	27	8.7	11.7	0.0
Hawaiian Islands																																
Honolulu	38	86	100	[1] 30.00	[1] 30.04		73.0		82	31	78	61	23	68	15	66	63	72	6.67	+3.5	21	7,286	e.	35	nw.	22	4	11	16	6.9	0.0	0.0

[1] Pressure not corrected to mean of 24 hours.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, March, 1927*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. + 2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*In.*	*In.*	*In.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*In.*	*In.*	*In.*
St. Johns, N. F.	125												
Sydney, C. B. I.	48												
Halifax, N. S.	88												
Yarmouth, N. S.	65												
Charlottetown, P. E. I.	38												
Chatham, N. B.	28												
Father Point, Que.	20	30.01	30.03	+0.13	26.3	+6.0	33.2	19.5	41	4	1.04	−1.69	3.0
Quebec, Que.	296	29.74	30.08	+.12	28.0	+6.8	34.5	21.6	48	3	2.12	−1.14	12.3
Montreal, Que.	187												
Stonecliffe, Ont.	489												
Ottawa, Ont.	230	29.83	30.11	+.10	31.3	+9.8	39.7	23.0	53	6	2.12	−0.60	5.9
Kingston, Ont.	285												
Toronto, Ont.	379	29.68	30.10	+.08	35.2	+7.9	41.7	28.7	59	10	2.26	−0.38	5.0
Cochrane, Ont.	930												
White River, Ont.	1,244	28.70	30.06	+.03	22.0	+9.8	35.3	8.8	54	−30	1.34	−0.04	5.2
Port Stanley, Ont.	592												
Southampton, Ont.	656												
Parry Sound, Ont.	688	29.37	30.09	+.07	30.2	+9.1	39.0	21.0	57	−2	1.03	−1.20	7.7
Port Arthur, Ont.	644	29.36	30.10	+.05	27.7	+10.9	35.0	20.5	49	−6	1.20	+0.23	3.0
Winnipeg, Man.	760	29.19	30.06	−.03	27.7	+15.4	35.6	19.7	52	−5	0.48	−0.55	4.6
Minnedosa, Man.	1,690												
Le Pas, Man.	860												
Qu'Appelle, Sask.	2,115	27.66	29.98	−.06	22.3	+7.4	30.8	13.9	47	−14	1.77	+1.00	17.6
Medicine Hat, Alb.	2,144	27.58	29.87	−.13	32.8	+5.3	41.2	24.5	58	0	1.01	+0.25	8.5
Moose Jaw, Sask.	1,759				25.6		33.9	17.3	51	−11	1.19		11.9
Swift Current, Sask.	2,392	27.32	29.91	−.11	27.2	+5.2	35.5	19.0	55	−11	1.42	+0.61	12.4
Calgary, Alb.	3,428												
Banff, Alb.	4,521	25.28	29.96	+.02	26.1	+5.9	37.9	14.3	48	−6	0.25	−1.16	2.5
Edmonton, Alb.	2,150	27.56	29.90	−.06	25.8	+1.6	34.9	16.7	50	−4	0.46	−0.26	3.9
Prince Albert, Sask.	1,450	28.40	30.03	−.05	22.3	+10.3	32.2	12.4	49	−14	1.44	+0.67	14.4
Battleford, Sask.	1,592												
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.81	30.07	+.10	44.0	+2.1	49.2	38.8	56	32	1.55	−1.57	0.0
Barkerville, B. C.	4,180												
Triangle Island, B. C.	680												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151	29.98	30.15	+.07	63.1	+0.9	70.6	55.7	75	45	2.44	−2.69	0.0

LATE REPORTS, FEBRUARY, 1927

Ottawa, Ont.	236	29.78	30.07	+0.05	17.7	+6.0	26.0	9.4	47	−16	3.68	+0.99	36.8
Winnipeg, Man.	760	29.22	30.11	+.01	6.5	+8.1	14.6	−1.5	41	−24	0.39	−0.59	3.4
Calgary, Alb.	3,428	26.30	30.03	+.04	16.7	+3.2	27.5	6.0	50	−30	0.70	+0.07	7.0
Kamloops, B. C.	1,262	28.65	29.98	+.02	27.9	−0.4	34.3	21.6	49	−2	0.77	−0.02	7.7
Barkerville, B. C.	4,180	25.45	29.84	−.07	20.1	+1.2	28.9	11.3	39	−28	1.89	−1.17	18.9
Prince Rupert, B. C.	170				38.6		44.0	33.2	49	11	6.51		1.0

Chart I. Tracks of Centers of Anticyclones, March, 1927. (Inset) Departure of Monthly Mean Pressure from Normal

Chart I. Tracks of Centers of Anticyclones, March, 1927. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by Wilfred P. Day)

Chart II. Tracks of Centers of Cyclones, March, 1927. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Wilfred P. Day)

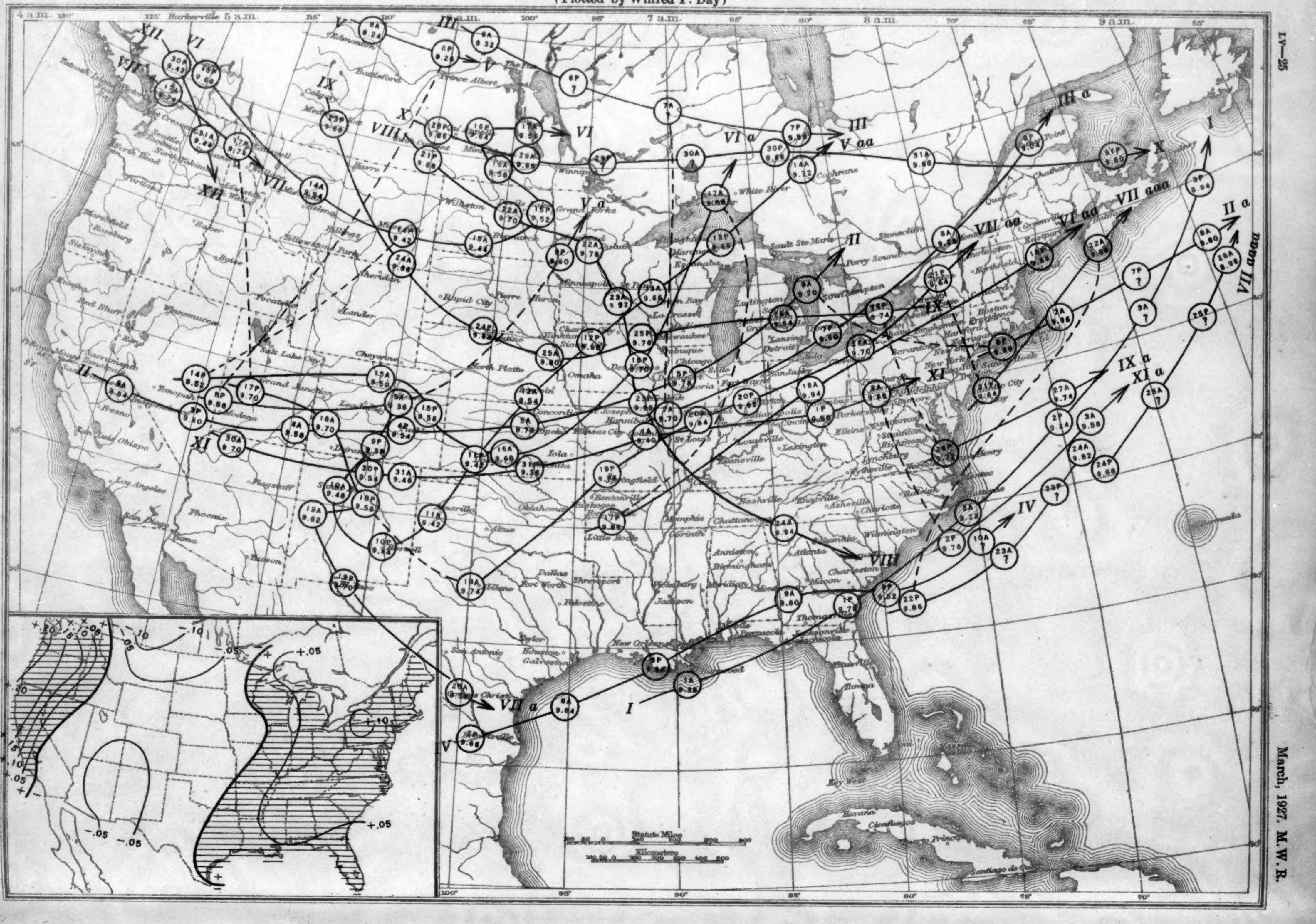

Chart III. Departure (°F.) of the Mean Temperature from the Normal, March, 1927

Chart III. Departure (°F.) of the Mean Temperature from the Normal, March, 1927

Shaded portions show excess (+).
Unshaded portions show deficiency (—).
Lines show amount of excess or deficiency.

Chart IV. Total Precipitation, Inches, March, 1927. (Inset) Departure of Precipitation from Normal

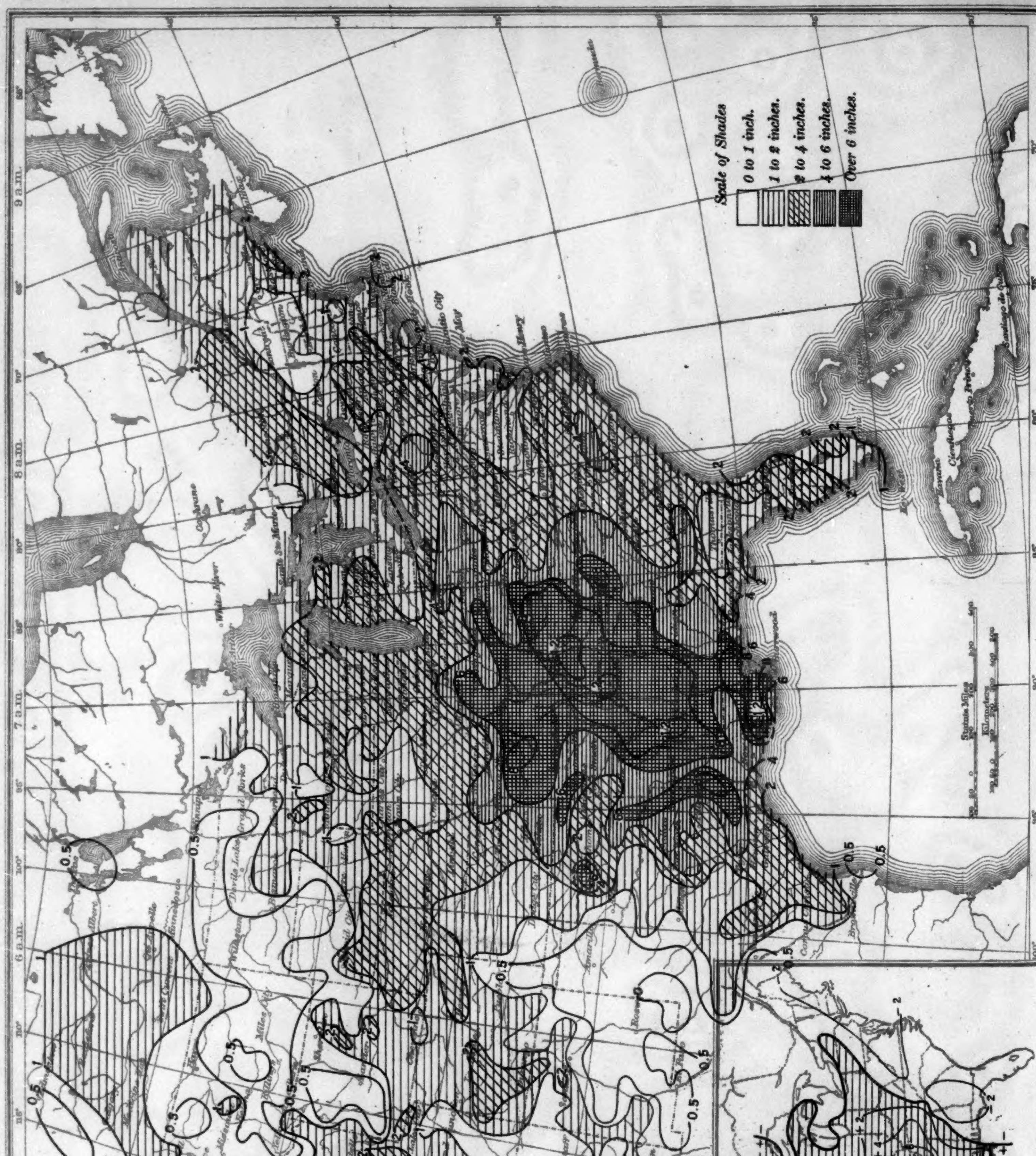

Chart V. Percentage of Clear Sky between Sunrise and Sunset, March, 1927

Chart V. Percentage of Clear Sky between Sunrise and Sunset, March, 1927

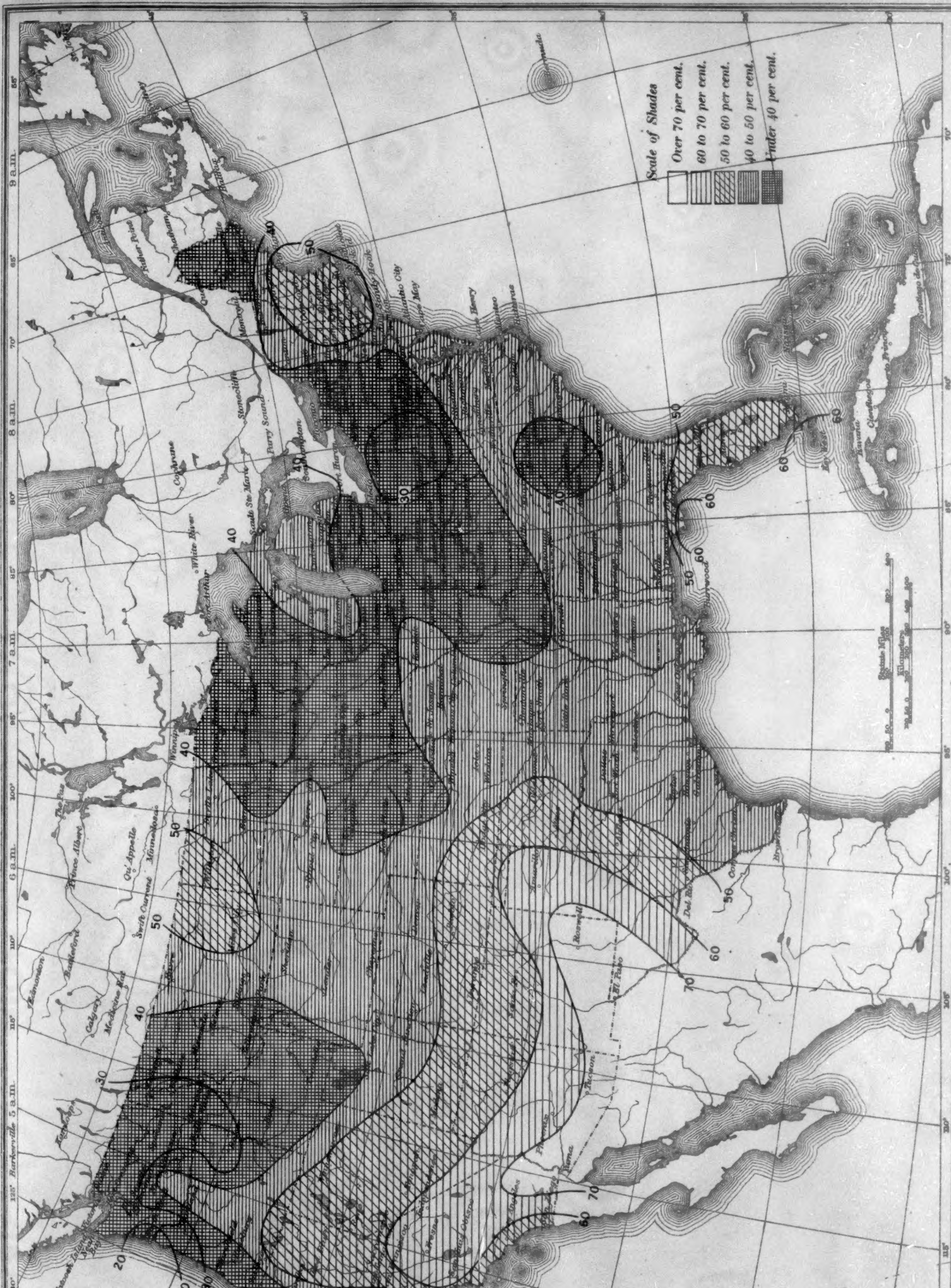

Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, March, 1927

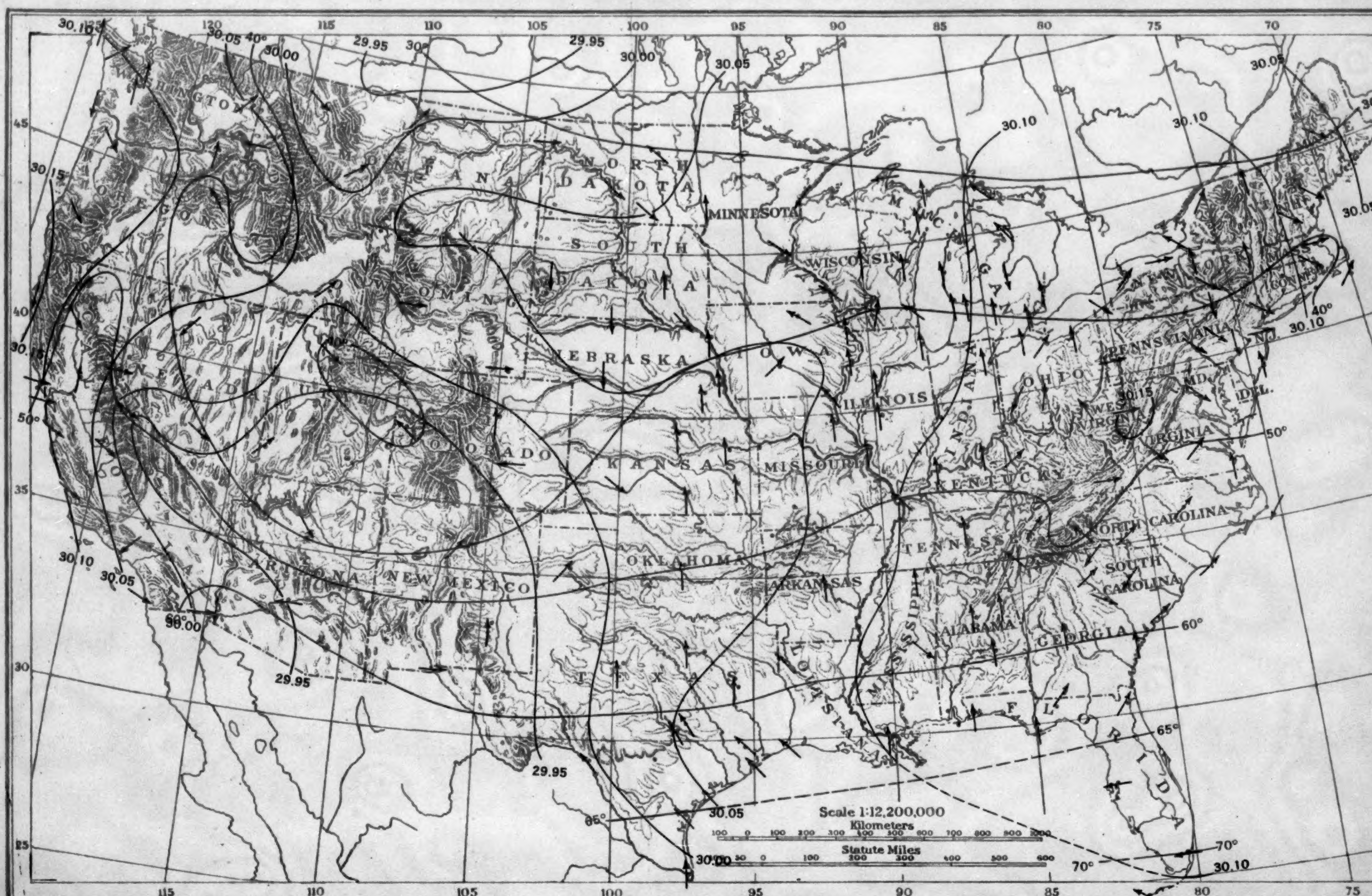

Chart VII. Total Snowfall, Inches, March, 1927. (Inset) Depth of Snow on Ground at end of Month

Chart VII. Total Snowfall, Inches, March, 1927. (Inset) Depth of Snow on Ground at end of Month

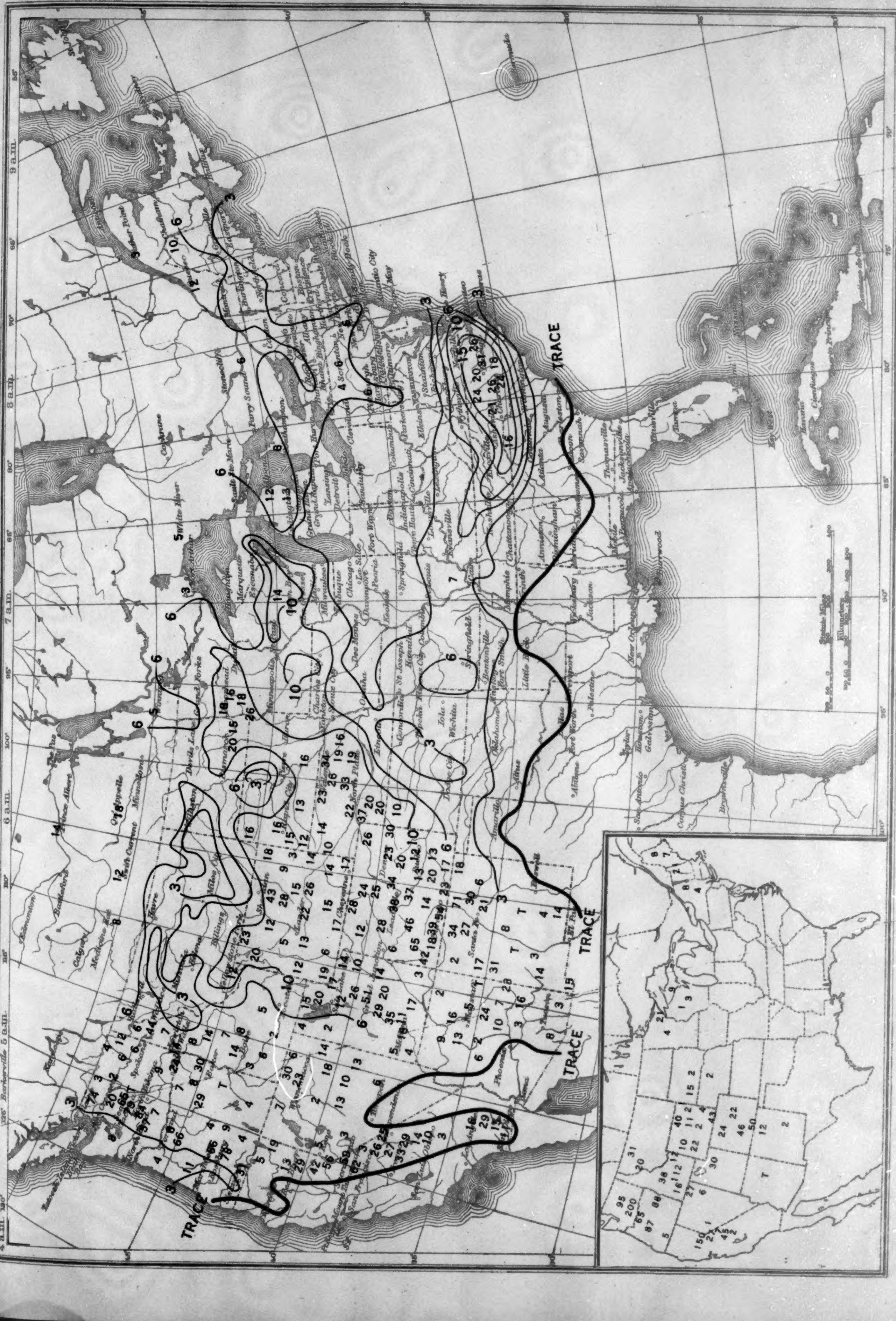

Chart VIII. Weather Map of North Atlantic Ocean, March 2, 1927
(Plotted by F. A. Young)

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(Plotted by F. A. Young)

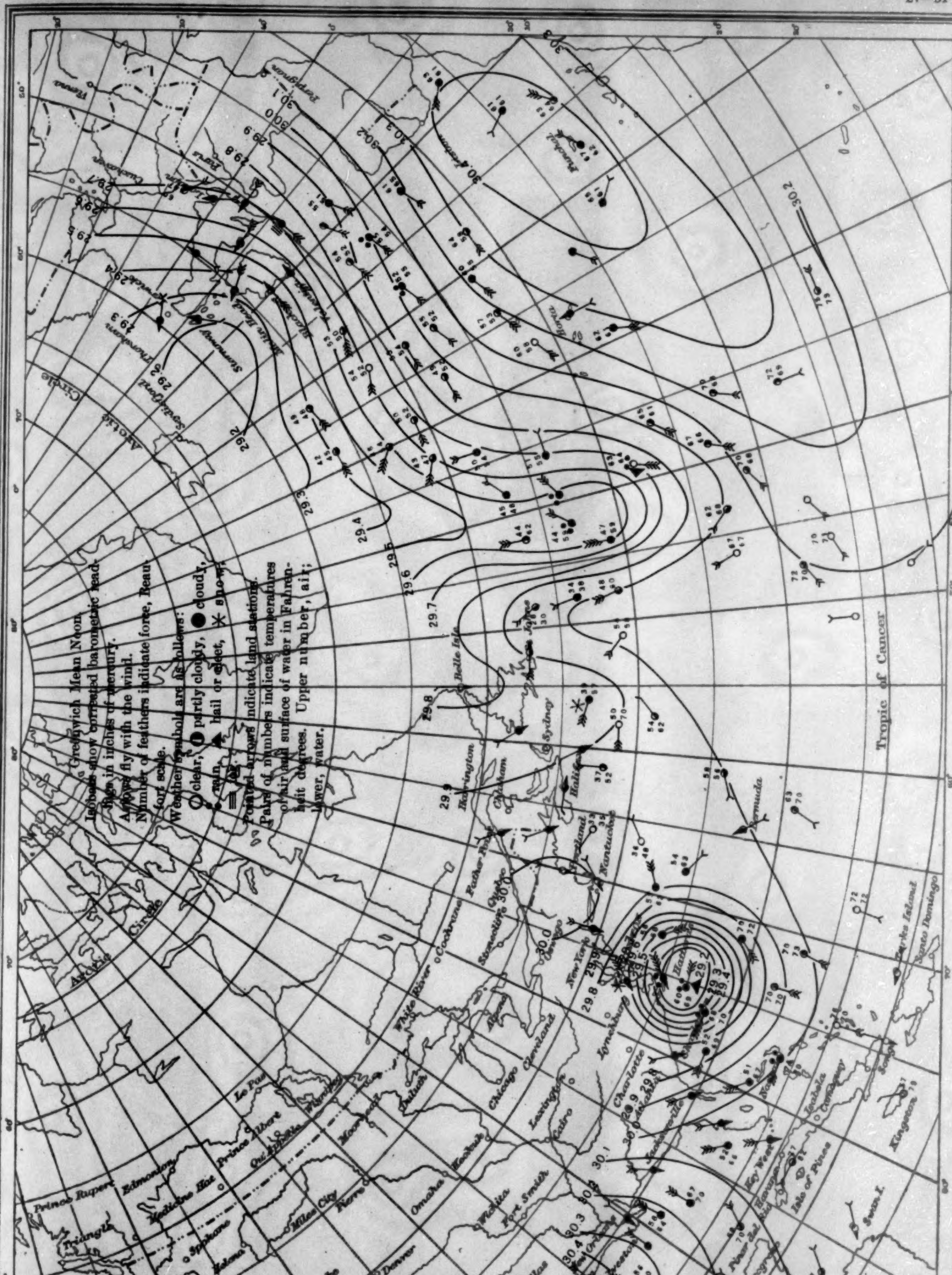

Chart IX. Weather Map of North Atlantic Ocean, March 3, 1927

(Plotted by F. A. Young)

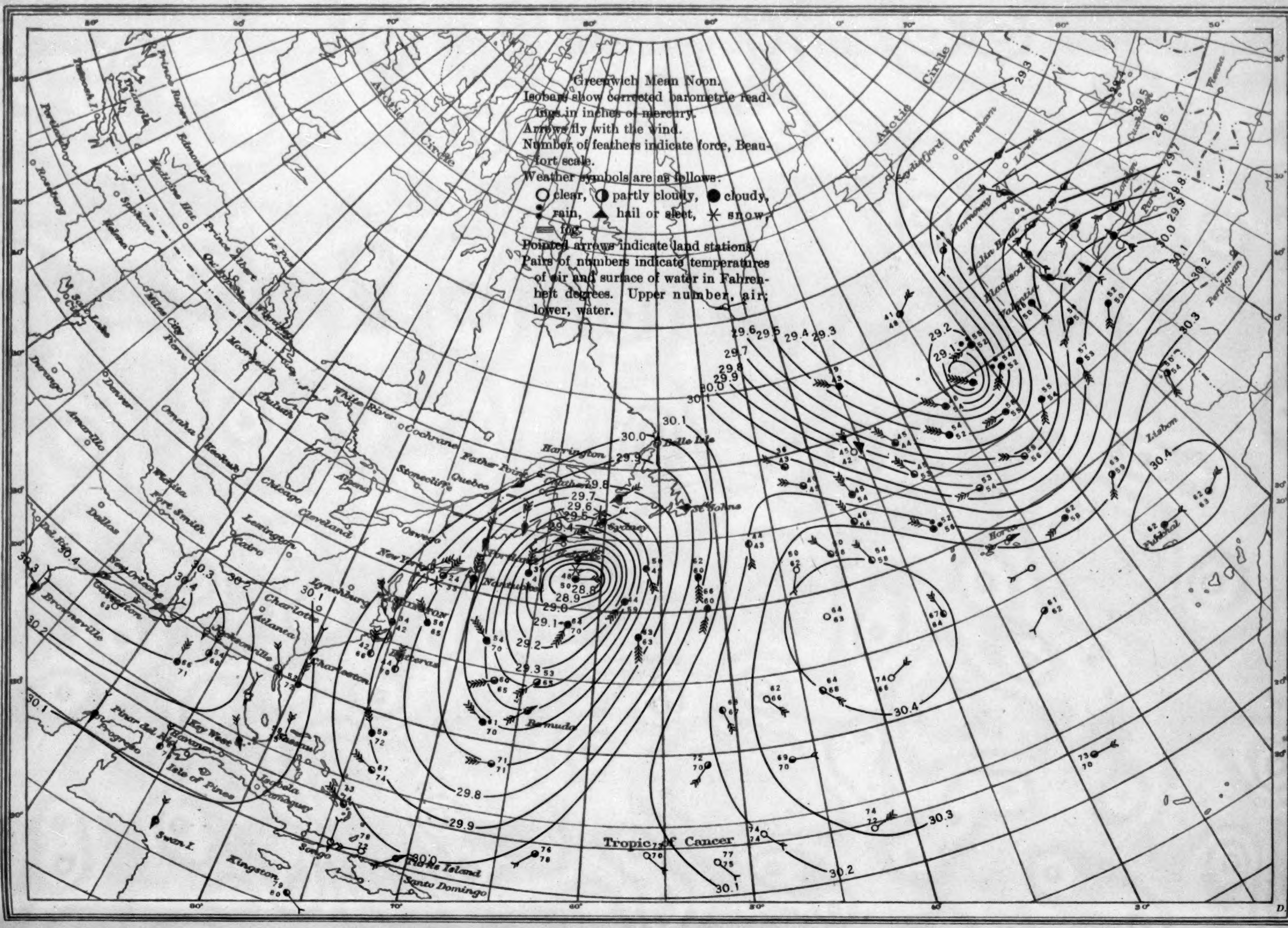

Chart X. Weather Map of North Atlantic Ocean, March 4, 1927

(Plotted by F. A. Young)

Chart X. Weather Map of North Atlantic Ocean, March 4, 1927
(Plotted by F. A. Young)

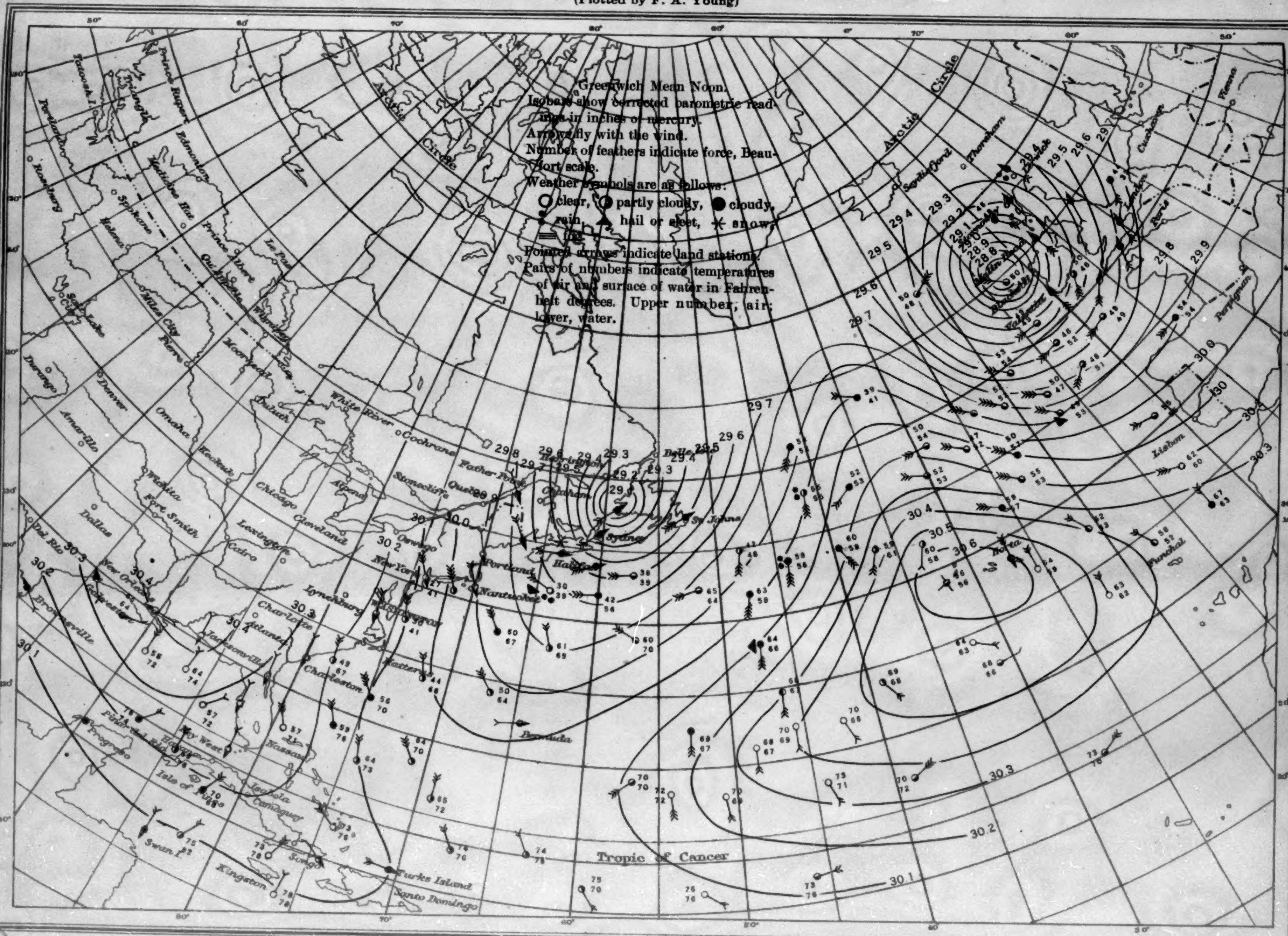

Chart XI. Weather Map of North Atlantic Ocean, March 5, 1927

(Plotted by F. A. Young)